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# PRACTICAL CHEMISTRY

J. CAMPBELL BROWN

ANALYTICAL TABLES

AND EXERCISES

FOR STUDENTS

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# PRACTICAL CHEMISTRY;

## ANALYTICAL TABLES

AND EXERCISES

## FOR STUDENTS.

BY

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SECOND EDITION.

LONDON:
J. AND A. CHURCHILL, 11, NEW BURLINGTON STREET.
LIVERPOOL: ADAM HOLDEN, 48, CHURCH STREET.

1882.

BIBL
DEC 82
BODLEIAN

LONDON:
HARRISON AND SONS, PRINTERS IN ORDINARY TO HER MAJESTY,
ST. MARTIN'S LANE.

# REACTIONS OF METALS.

## EXERCISE I.

### SOLUTION OF SODIUM CHLORIDE.

Take about one cubic centimetre of the solution in a test tube or test glass, and add to it—

1. A few drops of HCl (hydrochloric acid): no ppt.; then
2. A current of the $H_2S$ gas (hydrosulphuric acid): no ppt.

Take another similar quantity of the original solution and add to it—

3. $NH_4HO$ (ammonium hydrate): no ppt.; then
4. $(NH_4)_2S$ (ammonium sulphide): no ppt.; then
5. $(NH_4)_2CO_3$ (ammonium carbonate): no ppt.; then
6. $(NH_4)_3PO_4$ (ammonium phosphate): no ppt.
7. Take a few drops of the solution on a piece of platinum foil or in a small porcelain dish, and evaporate to dryness over a Bunsen flame or spirit lamp; a white crystalline residue remains; heat this residue to redness; it is not volatile.
8. Moisten the end of a platinum wire with water, pick up by this means a small particle of the ignited salt and insert it into a Bunsen flame or colourless blow-pipe flame; the flame is tinged orange-yellow. Characteristic line of the spectrum WL = 5890.
9. Make a strong solution of the ignited residue, or take a few drops of the original solution, add to it, on a watch glass, a few drops of HCl, then $PtCl_4$ (platinic chloride), and stir with a clean glass rod, no ppt. After careful evaporation to dryness the yellow crystals which are formed are soluble in water and in a mixture of alcohol and ether.
10. Chloride of sodium is insoluble in a mixture of alcohol and ether.

## EXERCISE II.

### SOLUTION OF POTASSIUM CHLORIDE.

1 to 6. Take about 1 c.c. of the solution in each of two test tubes, and add to them the same reagents as in experiments 1, 2, 3, 4, 5, and 6 of the last exercise—with similar results.

7. Evaporate a small quantity of the solution to dryness, and heat the residue to red heat. It is not volatile.

8. Place a small portion of the ignited salt or of the original solution in a colourless flame. If the potassium salt is pure the flame is tinged violet; if the salt contains a minute quantity of sodium salt the flame is tinged orange. On viewing the mixed flame through blue glass the orange rays are absorbed, and the violet rays are thus rendered visible. Characteristic lines of spectrum WL = 7700, 6950, and 4080.

9. Make a strong solution of the ignited residue, or take a few drops of the original solution, add to it, on a watch glass, a few drops of HCl, then a few drops of $PtCl_4$, and stir with a glass rod. A yellow crystalline precipitate ($2KCl, PtCl_4$) is formed, which is also insoluble in a mixture of alcohol and ether. If a weak solution is used the solution must be evaporated to dryness and treated with water.

10. To a portion of the solution add $H_2C_4H_4O_6$ (tartaric acid), and shake vigorously. A white crystalline precipitate ($KHC_4H_4O_6$) is produced, unless the solutions are very weak. The ppt. is increased by the addition of alcohol.

11. To another portion of the solution add trinitrophenol (picric acid): yellow insoluble silky needles ($C_6H_2(NO_2)_3KO$) are produced.

12. Chloride of Potassium is insoluble in a mixture of alcohol and ether.

13. $H_2SiF_6$ (hydrofluosilicic acid) gives a white gelatinous precipitate ($K_2SiF_6$) with potassium salts.

## EXERCISE III.

### SOLUTION OF CHLORIDE OF LITHIUM.

1. Lithium chloride is soluble in a mixture of alcohol and ether, and may thus be separated from chlorides of potassium and sodium.

2 to 8. Repeat experiments 1 to 7 of the last two exercises, with similar results.*

9. Place a small portion of lithium chloride in a colourless flame, or set fire to a small quantity of the alcoholic solution. Lithium imparts a bright crimson colour to the flame.

Characteristic lines of spectrum, a red line $\alpha$, WL = 6705, and a weaker orange one $\beta$, WL = 6101.

## EXERCISE IV.

### SOLUTION OF AMMONIUM CHLORIDE.

1 to 6. Repeat experiments 1 to 6 as in exercises I and II.

7. Take a third portion of the solution in a small porcelain dish, evaporate it to dryness, and ignite the residue to redness over a Bunsen flame. White fumes of neutral ammoniun chloride are produced by the sublimation of the salt until it has been entirely removed from the hot dish.

8. Introduce a small quantity of the dry residue, obtained by evaporation, into a colourless flame; the flame is temporarily tinged yellow or orange.

9, 10, and 11. Repeat experiments 9 to 11 of the exercise on chloride of potassium, with similar results.

12. Add Nessler's reagent (potassic solution of $2KI,HgI_2$): brown ppt. ($Hg_4N_2I_2, 2H_2O$).

13. Heat in a test-tube a small portion of the solution with solution of caustic soda ($NaHO$) or with lime ($CaH_2O_2$), while a piece of moistened red litmus paper is held over the mouth of the tube; the ammonia gas evolved renders the litmus blue, and may also be detected by its odour.

## EXERCISE V.

### SOLUTION OF MAGNESIUM CHLORIDE.

Take about 1 c.c. of the solution, and add to it—

1. A few drops of $HCl$: no ppt.; then

2. A current of $H_2S$ gas: no ppt.

Take another similar quantity of the original solution, and add to it—

3. $NH_4HO$: a ppt. may be formed; add now $NH_4Cl$: the ppt., if any, dissolves; then

---

* The carbonates and phosphates of Lithium are not very soluble in water, therefore if the solutions are very concentrated, carbonates and phosphates of the other alkalies may partially precipitate Lithium salts.

4. $(NH_4)_2S$: no ppt.; then

5. $(NH_4)_2CO_3$: no ppt., unless insufficient $NH_4Cl$ is present; then

6. $(NH_4)_3PO_4$, and $NH_4HO$: a white crystalline ppt. falls ($MgNH_4PO_4,6H_2O$), which is increased on stirring and allowing to stand for some time.

To other portions of the original solution add—

7. $H_2SO_4$ (sulphuric acid): no ppt.

8. Ammonium hydrate, $NH_4Cl$, and $(NH_4)_2C_2O_4$ (ammonium oxalate): no ppt.

9. Evaporate to dryness, and ignite a portion, either on charcoal or otherwise, moisten with $Co2NO_3$ in blow-pipe flame: dirty pale pink mass is produced.

10. It does not colour a Bunsen flame.

## EXERCISE VI.

### SOLUTION OF CALCIUM CHLORIDE.

1 to 4. Repeat experiments 1 to 4 of the preceding exercise, with negative results.

To other portions of the solution add—

5. $(NH_4)_2CO_3$: a bulky white ppt. ($CaCO_3$).

6. $(NH_4)_3PO_4$ and $NH_4HO$: a bulky white ppt. ($Ca_3P_2O_8$).

7. $NH_4HO$ and $(NH_4)_2C_2O_4$ first to a strong solution, and second to an extremely dilute solution: a white ppt. or cloud ($CaC_2O_4$) is at once formed in each case; soluble in HCl and $HNO_3$, but insoluble in $HC_2H_3O_2$ (acetic acid).

8. $H_4SO_4$ first to a strong solution: white ppt. ($CaSO_4$); and second to a very dilute solution; no ppt.

9. Place a small portion, by means of a chemically clean platinum wire, in a colourless flame. Calcium tinges the flame orange-red. Characteristic lines of spectrum WL = 6170, 5550, 4230.

## EXERCISE VII.

### SOLUTION OF STRONTIUM CHLORIDE.

1 to 8. Repeat experiments 1 to 8 inclusive, of the preceding exercise, with similar results, except that a cloud with very dilute solutions in experiments 7 and 8 appears slowly.

9. Introduce a small portion into a colourless flame. Strontium tinges the flame crimson. Spectrum characteristic blue line WL = 4607 and red bands.

## EXERCISE VIII.

### SOLUTION OF BARIUM CHLORIDE.

1 to 6. Repeat experiments 1 to 6 of the last two exercises with similar results.

7. Add $NH_4HO$ and $(NH_4)_2CO_3$: a white ppt. is formed if the solutions are of ordinary strength, but no cloud is formed if the solutions are extremely dilute.

8. Add dilute $H_2SO_4$: an immediate white ppt. ($BaSO_4$), even if the solutions are extremely dilute.

9. Add solution of $CaSO_4$ (calcium sulphate): an immediate white cloud is formed, $BaSO_4$ being more insoluble than $CaSO_4$.

10. Place a small portion in a colourless flame, by means of a clean platinum wire. Barium tinges the flame olive-green. The spectrum consists of red or orange and green bands, from WL = 7000 to 4350.

In the case of a non-volatile salt, such as sulphate, the wire should be moistened with HCl.

11. $H_2SiF_6$ gives a white crystalline ppt. ($BaSiF_6$).

12. $K_2CrO_4$ gives a yellow ppt. ($BaCrO_4$) in dilute neutral solutions.

## EXERCISE IX.

### SOLUTION OF ZINC CHLORIDE OR SULPHATE.

1 and 2. Repeat experiments 1 and 2 of the previous exercises: negative results.

To other portions of the original solution add—

3. $NH_4HO$: colourless ppt. ($ZnH_2O_2$) if ammonium salts are absent; soluble in excess; soluble also in ammonium salts.

4. $(NH_4)_2S$: a white ppt. of ZnS; soluble in mineral acids, but not soluble in acetic acid ($HC_2H_3O_2$).

5. NaHO: colourless ppt. ($ZnH_2O_2$); soluble in excess.

6. $(NH_4)_2CO_3$: white ppt.; soluble in excess.

7. $K_4Cfy$: yellow-white ppt. ($Zn_2Cfy$).

*Experiments with Dry Compounds of Zinc.*

8. Heat a portion on charcoal in blow-pipe flame; ZnO is reduced, which becomes yellow when hot, white when cold; then

9. Moisten with $Co2NO_3$: and heat again in blow-pipe flame: the mass becomes green (Rinman's green pigment).

## EXERCISE X.

### SOLUTION OF MANGANESE CHLORIDE.

1 and 2. Repeat 1 and 2 of the previous exercises, with negative results.

To other portions of the original solution add—

3. $NH_4HO$: white ppt. ($MnH_2O_2$); soluble in $NH_4Cl$; changing by exposure to air into a brown ppt. of $MnH_3O_3$, not soluble in $NH_4Cl$.

4. $(NH_4)_2S$: a pink ppt. of MnS, soluble in acetic acid when recently precipitated.

5. NaHO: white ppt.; insoluble in excess, becoming brown by exposure to air.

6. $(NH_4)_2CO_3$: white ppt. of $MnCO_3$, becoming brown by exposure.

7. $K_4Cfy$: white ppt. of $Mn_2Cfy$.

*Experiments with Dry Compounds of Manganese.*

8. Make a borax bead, introducing a very small quantity of the original substance, or any of its precipitates: colourless in the inner, amethyst bead in the outer blow-pipe flame.

9. Fuse a portion on platinum foil with $Na_2CO_3$ and $KNO_3$: green mass of alkaline manganates ($K_2MnO_4$).

## EXERCISE XI.

### SOLUTION OF NICKEL SULPHATE.

1 and 2. Repeat experiments 1 and 2 of the previous exercises, with negative results.

To another portion of the original solution add—

3. $NH_4HO$: light green ppt. ($NiH_2O_2$); soluble in excess, forming a blue solution.

4. To another portion add $NH_4Cl$ and $NH_4HO$: no ppt.

5. Then add $(NH_4)_2S$: black ppt. (NiS); insoluble in HCl and in $HC_2H_3O_2$.

To other portions of the original solution—

6. NaHO: light green ppt. ($NiH_2O_2$); insoluble in excess.

7. Solution of NaClO (bleaching solution), and boil: black ppt. of $NiH_3O_3$.

8. $(NH_4)_2CO_3$: green ppt. ($NiCO_3$); soluble in excess.

9. KCy: greenish ppt. ($NiCy_2$); soluble in excess, forming a light brown solution of 2KCy, $NiCy_2$; reprecipitated by acids.

10. $K_4Cfy$: greenish ppt. ($Ni_2Cfy$).
11. Borax bead: grey in inner, red in outer flame.

## EXERCISE XII.

### SOLUTION OF COBALT CHLORIDE.

1 and 2. Repeat experiments 1 and 2 of the previous exercises, with negative results.

To another portion of the solution add—

3. $NH_4HO$: blue ppt. ($CoH_2O_2$, $CoCl_2$); soluble in excess, forming a brown solution.

To another portion add—

4. $NH_4Cl$ and $NH_4HO$: no ppt.

5. Then add $(NH_4)_2S$: black ppt. ($CoS$); insoluble in $HCl$ and $HC_2H_3O_2$.

To other portions of the original solution add—

6. $NaHO$: blue ppt. ($CoH_2O_2$, $CoCl_2$); insoluble in excess.

7. Solution of $NaClO$, and boil: black ppt. of $CoH_3O_3$.

8. $(NH_4)_2CO_3$: rose-red ppt.; soluble in excess.

9. $KCy$: brown ppt. ($CoCy_2$); soluble in excess ($2KCy$, $CoCy_2$); forming, on boiling with a drop of $HCl$ (to liberate $HCy$), $K_3CoCy_6$; not precipitated by $HCl$ nor by $NaClO$.

10. $K_4Cfy$: dark green ppt. ($Co_2Cfy$).

11. $KCsy$, and evaporate to dryness in a porcelain dish: a blue residue.

12. Make a borax bead, containing a trace of a dry compound of cobalt: deep blue bead.

## EXERCISE XIII.

### SOLUTION OF FERROUS CHLORIDE.

1 and 2. Repeat experiments 1 and 2 of previous exercises, with negative results.

To other portions of the solution add—

3. $NH_4HO$: white ppt. ($FeH_2O_2$); soluble in $NH_4Cl$, becoming greenish-black ($Fe_3O_4$), then reddish-brown, on exposure.

4. $NaHO$: the same ppt.; insoluble in $NH_4Cl$; insoluble in excess.

5. $(NH_4)_2S$: black ppt. ($FeS$).

6. $(NH_4)_2CO_3$: greenish-white ppt. ($FeCO_3$).

7. $K_4Cfy$: pale blue ppt. ($Fe''K_2Cfy$); becoming dark blue on exposure.

8. $K_3Cfdy$: deep blue ppt., $Fe_3''(Cy_6Fe''')_2$.
9. Borax bead: green in inner, bottle-red in outer flame.

## EXERCISE XIV.

### SOLUTION OF FERRIC CHLORIDE.

To a portion of the solution add—

1. $HCl$: no ppt.; then
2. $H_2S$: sulphur is precipitated and $Fe_2Cl_6$ is reduced to $FeCl_2$.

To other portions of the solution add—

3. $NH_4HO$: red ppt. ($FeH_3O_3$); insoluble in excess, and not altered by $NH_4Cl$; but no precipitate in the presence of some organic substances, *e.g.*, citric acid.
4. $(NH_4)_2S$: black ppt. of $FeS$ mixed with sulphur.
5. $NaHO$: red ppt. ($FeH_3O_3$); insoluble in excess.
6. $(NH_4)_2CO_3$: red ppt., with evolution of $CO_2$.
7. $(NH_4)_3PO_4$: reddish-white ppt. ($FePO_4$).
8. $K_4Cfy$: Prussian blue ppt.; decomposed by alkalies, not by acids, $Fe'''_4(Cy_6Fe'')_3$.
9. $K_3Cfdy$: no ppt; greenish-red solution.
10. $KCsy$: blood-red solution.
11. Tannic or gallic acid: inky solution.
12. Borax bead: red in the outer flame.

## EXERCISE XV.

### SOLUTION OF CHLORIDE OF ALUMINIUM.

To a portion of the solution add—

1. $HCl$: no ppt.
2. Then pass a current of $H_2S$ gas through the solution: no ppt.

To other portions of the solution add—

3. $NH_4HO$: a white gelatinous ppt. ($AlH_3O_3$); not altered by excess, nor by $NH_4Cl$.
4. $(NH_4)_2S$: the same gelatinous ppt. of oxide; there being no sulphide of aluminium.
5. $NaHO$: white gelatinous ppt. ($AlH_3O_3$); soluble in excess ($Na_3AlO_3$), not reprecipitated by boiling.
6. $(NH_4)_2CO_3$: white ppt.
7. $(NH_4)_3PO_4$: white ppt. ($AlPO_4$); soluble in $NaHO$, insoluble in $NH_4Cl$.
8. Take a small portion of alumina or of alum, and heat on charcoal with a drop of $Co2NO_3$: blue mass.

## EXERCISE XVI.

### SOLUTION OF CHROMIUM CHLORIDE.

To portions of the solution add—

1. HCl : no ppt.
2. $H_2S$ : no ppt.
3. $NH_4HO$: green ppt., $CrH_3O_3$; not soluble in excess, nor in $NH_4Cl$.
4. $(NH_4)_2S$ : green ppt. of $CrH_3O_3$; insoluble in excess.
5. NaHO: green ppt. $CrH_3O_3$; soluble in excess, and reprecipitated (as $Cr_2O_3$) on boiling.
6. $(NH_4)_2CO_3$ : green ppt.

*Experiments with Oxide of Chromium.*

7. Borax bead : emerald-green in both flames.
8. Fuse on a piece of platinum foil with $Na_2CO_3$ and $KNO_3$: yellow mass of alkaline chromate, $K_2CrO_4$.

## EXERCISE XVII.

### INSOLUBLE PHOSPHATES.

Dissolve a portion of each of the substances in HCl:

1. To a small portion add ammonium nitro-molybdate in large excess, and heat to boiling: a yellow crystalline powder of ammonium phospho-molybdate is formed.

2. To another portion of the solution add, $NH_4HO$: aluminium phosphate is white, insoluble in excess and in acetic acid. Iron phosphate is insoluble in excess and also in acetic acid in the cold. Alkaline earthy phosphates are insoluble in excess but soluble in acetic acid.

3. To another portion add NaHO. Chromium and aluminium phosphate dissolve, the iron and alkaline earthy phosphates remain insoluble.

4. Mix a portion of the solution of phosphates of the alkaline earths with $Fe_2Cl_6$, then add NaHO until a ppt. is just formed; redissolve the ppt. with acetic acid and boil until no red colour remains in the solution. Filter and test the filtrate for the alkaline earths; all the phosphate should be found as ferric phosphate in the ppt.

## EXERCISE XVIII.

### SOLUTION OF LEAD ACETATE.

1. To a portion of the solution add HCl: white crystalline ppt. of $PbCl_2$. Filter and add $H_2S$ to the filtrate: a slight black ppt. is formed, showing that $PbCl_2$ is not absolutely insoluble in acidulated water.

2. Boil the ppt. of $PbCl_2$ with a large quantity of water, and add to one portion of the solution $H_2SO_4$: a white ppt. of $PbSO_4$ is formed, soluble in ammoniacal solution of tartaric acid.

3. To another portion of the $PbCl_2$ solution add KI: yellow ppt. of $Pb\ I_2$; soluble in excess and in boiling water.

To small portions of the original solution add—

4. $NH_4HO$: white ppt.; insoluble in excess.

5. NaHO: white ppt. of $PbH_2O_2$; soluble in excess.

6. $K_2Cr_2O_7$: chrome-yellow ppt. of $PbCrO_4$; soluble in NaHO.

7. Evaporate a portion of the solution to dryness, or take any lead compound and heat on charcoal in the inner blow-pipe flame: a soft malleable metal is reduced, and in the outer flame an oxide is formed which is reddish-brown when hot and yellow when cold.

## EXERCISE XIX.

### SOLUTION OF SILVER NITRATE.

To small portions of the solution add—

1. HCl: curdy white ppt. of AgCl; soluble in $NH_4HO$, and in KCy; insoluble in boiling water and in acids; soluble also in sodium hyposulphite.

2. $H_2S$: black ppt. of $Ag_2S$; insoluble in $(NH_4)_2S$.

3. $NH_4HO$: grey ppt.; easily soluble in excess.

4. NaHO: grey ppt. of $Ag_2O$; insoluble in excess.

5. $Na_2CO_3$: white ppt. of $Ag_2CO_3$; insoluble in excess.

6. $H_2SO_4$: no ppt.

7. KI: pale yellow ppt. of AgI; insoluble in $HNO_3$ and in $NH_4HO$.

8. KCy: curdy white ppt. of AgCy; soluble in excess and in $NH_4HO$.

9. $K_2Cr_2O_7$: dark red ppt. of $Ag_2CrO_4$.

10. Evaporate to dryness, or take any of the silver ppt. and heat on charcoal with or without $Na_2CO_3$ in the inner blow-pipe flame: a hard shining malleable metal is reduced.

## EXERCISE XX.

### SOLUTION OF MERCUROUS NITRATE.

To small portions of the solution add—

1. HCl: white ppt., insoluble in but blackened by $NH_4HO$.
2. $H_2S$: dirty white, then red, then black, ppt. of $Hg_2S$; insoluble in $(NH_4)_2S$, and in dilute acids.
3. $NH_4HO$: black ppt. ($Hg_4H_4N_2\ 2NO_3$); insoluble in excess.
4. NaHO: dark grey ppt. of $Hg_2O$.
5. $Na_2CO_3$: white ppt.
6. $H_2SO_4$: no ppt.
7. KI: green ppt. of $Hg_2I_2$.
8. $K_2Cr_2O_7$: red ppt.
9. $SnCl_2$: grey ppt. of metallic mercury.
10. Heat any dry mercurous compound on charcoal, or in a tube; the metal is reduced and volatilized, and sublimes in the cool part of the tube in the form of a mirror composed of minute globules.
11. Reinsch's test: acidulate a portion of any mercurous compound in a tube with HCl and boil with a strip of pure electrolytic copper. A film of metallic mercury is reduced on the surface of the copper. Dry between blotting paper and heat in a tube; the mercury sublimes, leaving the copper of its natural colour.

## EXERCISE XXI.

### SOLUTION OF MERCURIC CHLORIDE.

1. To a portion of the solution add HCl: no ppt.; then
2. $H_2S$: white, then yellow and red ppt. of $HgSHgCl_2$; and finally black ppt. of HgS; insoluble in $(NH_4)_2S$, in NaHO, and in $HNO_3$.

To small portions of the original solution add—

3. $NH_4HO$: white ppt. of $H_4Hg_2N_2Cl_2$; insoluble in excess.
4. NaHO: yellow ppt. of HgO; insoluble in excess.
5. $Na_2CO_3$: brown ppt.; insoluble in excess.
6. $H_2SO_4$: no ppt.
7. KI: scarlet ppt. ($HgI_2$); soluble in excess of either solution.
8. $K_2Cr_2O_7$: no ppt. (yellow ppt. with $K_2CrO_4$).
9. $SnCl_2$: white ppt. of $Hg_2Cl_2$; when boiled with excess, a grey ppt. of metallic mercury.

10 and 11. Repeat the experiments 10 and 11 in the exercise upon mercurous nitrate, with similar results. (HgI volatilizes yellow.)

## EXERCISE XXII.

### SOLUTION OF $Bi3NO_3$.

To portions of the solution add—

1. $HCl$: no ppt.; but a large quantity of water, or even dilute $HCl$ will ppt. white $BiOCl$ insoluble in $KHO$ and in solution of $KHC_4H_4O_6$ (cream of tartar).
2. $H_2S$: dark brown ppt. of $Bi_2S_3$; insoluble in $(NH_4)_2$ S.
3. $NH_4HO$: white ppt. ($BiH_3O_3$); insoluble in excess.
4. $NaHO$: white ppt. ($BiH_3O_3$); insoluble in excess.
5. $KI$: brown ppt. $BiI_3$; soluble in excess.
6. $KCy$: white ppt.; insoluble in excess.
7. $K_2Cr_2O_7$: yellow ppt.; insoluble in $NaHO$.
8. Evaporate a portion to dryness, or take one of the precipitates and heat on charcoal in the inner blow-pipe flame: a brittle metal is reduced, which forms in the outer flame an oxide, orange when hot, yellow on cooling.

## EXERCISE XXIII.

### SOLUTION OF COPPER SULPHATE OR CHLORIDE.

To portions of the solution add—

1. $HCl$: no ppt.
2. $H_2S$: black ppt. of $CuS$; insoluble in $(NH_4)_2S$.
3. $NH_4HO$: light blue ppt. ($CuH_2O_2$); dissolving in excess to a deep blue solution, which is decolorised by $KCy$.
4. $NaHO$: light blue ppt. ($CuH_2O_2$); insoluble in excess except in the presence of glucose.
5. $K_4Cfy$: chocolate-red ppt. ($Cu_2Cfy$).
6. $KI$: drab-coloured ppt. of $Cu_2I_2$.
7. $KCy$: greenish ppt.; soluble in excess.
8. $K_2Cr_2O_7$: red ppt.; soluble in $NH_4HO$.
9. A strip of iron is partly dissolved, while metallic copper is deposited on its surface.

## EXERCISE XXIV.

### SOLUTION OF CADMIUM SULPHATE.

To a portion of the solution add—

1. $HCl$: no ppt.
2. $H_2S$ solution and gas: yellow ppt. of $CdS$; insoluble in $(NH_4)_2CO_3$, in $NaHO$, and in $(NH_4)_2S$.

3. $NH_4HO$: white ppt. of $CdH_2O_2$; soluble in excess.
4. $(NH_4)_2S$: yellow ppt. of CdS.
5. NaHO: white ppt. of $CdH_2O_2$; insoluble in excess.
6. KI: no ppt.
7. KCy: white ppt.; soluble in excess.
8. Evaporate a portion to dryness, and heat on charcoal in the blow-pipe flame: a reddish-brown residue remains.

## EXERCISE XXV.

### SOLUTION OF STANNOUS CHLORIDE.

To small portions of the solution add—

1. HCl: no ppt.
2. $H_2S$: dark brown ppt. of SnS; soluble in NaHO, and soluble with difficulty in yellow ammonium polysulphide.
3. NaHO: white ppt. of $2SnO,H_2O$; soluble in excess ($Na_2SnO_2$).
4. $HgCl_2$: white ppt. of $Hg_2Cl_2$, and with excess of $SnCl_2$, a grey ppt. of finely divided mercury.
5. $AuCl_3$: a ppt. of purple of Cassius.
6. Heat on charcoal with KCy in the inner blow-pipe flame metallic tin is with some difficulty reduced.
7. Heat the $NH_4HO$ ppt. in the blow-pipe flame. The oxide becomes yellowish-brown when hot, and dirty yellow on cooling.

## EXERCISE XXVI.

### METALLIC TIN AND SOLUTION OF $SnCl_4$.

1. To a few grains of tin in a test tube add $HNO_3$, and heat: red fumes of $N_2O_2$ and $N_2O_4$ are evolved, and there remains a white powder of $Sn_5O_{10},10H_2O$, insoluble in acids and in solution of NaHO, but soluble after fusion in NaHO.
2. Boil a few grains of tin with HCl, adding one drop of $HNO_3$ from time to time to promote the solution of the tin, but not so as to form $Sn_5O_{10}$: hydrogen gas is evolved, and $SnCl_4$ (stannic chloride), is formed.

To small portions of a solution of stannic salt add—

3. $H_2S$: yellow ppt. ($SnS_2$), soluble by boiling in either NaHO or in yellow ammonium sulphide, forming $(NH_4)_2SnS_3$.
4. $NH_4HO$: white ppt. of $H_2SnO_3$; soluble in excess; no ppt. in the presence of tartaric acid.
5. NaHO: white ppt.; soluble in excess.
6. Repeat experiments 6 and 7 of last exercise.

## EXERCISE XXVII.

### METALLIC ANTIMONY AND SOLUTION OF ANTIMONY CHLORIDE.

1. Boil a few grains of antimony in nitric acid: red fumes are evolved, and a white powder remains ($Sb_2O_5,H_2O$), insoluble in acids and alkalies, and not dissolved after fusion with NaHO, but soluble by fusion with KHO.

2. Boil a few grains of antimony in HCl, adding a drop of $HNO_3$ from time to time to promote solution of the metal; concentrate the solution and dilute with water: a white cloud of ($5Sb_2O_3, 2SbCl_3$) is pptd.; soluble in KHO and in $KHC_4H_4O_6$.

Take small portions of solution of antimony and add—

3. HCl: a white ppt. only if dilute, not if the acid is sufficiently strong.

4. $H_2S$: orange ppt. ($Sb_2S_3$), soluble in NaHO and in $(NH_4)_2S$; soluble also by boiling in HCl.

5. $NH_4HO$ in HCl: white ppt.; insoluble in excess.

6. NaHO: white ppt.; soluble in excess.

7. Place a portion of any antimony compound in a hydrogen generator, arranged so that a jet of hydrogen can be burned: the flame has a livid white colour, and deposits a black film of antimony on a cold porcelain plate held in the flame. The stain is whitened by nitric acid, and is not attacked by solution of bleaching powder.

8. Boil a portion with copper, as in Reinsch's test: the metal is pptd. on the copper, and is not so volatile as arsenic.

9. Heat any dry compound on charcoal in the blow-pipe flame: it is reduced, then volatilised, and forms a semi-transparent white film of oxide on the charcoal.

## EXERCISE XXVIII.

### SOLUTION OF ARSENIOUS COMPOUNDS.

1. To a portion of the solution add pure HCl: no ppt.; then

2. $H_2S$: yellow ppt. ($As_2S_3$); soluble in $NH_4HCO_3$, in alkalies and in $(NH_4)_2S$.

To another solution prepared by boiling $As_2O_3$ in water add—

3. $AgNO_3$: no ppt., but on exactly neutralizing by $NH_4HO$; lemon-yellow ppt. of $Ag_3AsO_3$, soluble in $NH_4HO$.

4. To another portion add a few drops of $CuSO_4$: no ppt.,

until exactly neutralized by $NH_4HO$, when a ppt. of Scheele's emerald-green is formed, $CuHAsO_3$.

5. Repeat experiment 7 of the exercise on antimony; the metallic deposit is soluble in $HNO_3$ and in bleaching solution.

6. Repeat Reinsch's test, by boiling a portion of the substance with HCl and a strip of pure copper foil: an alloy of arsenic and copper is deposited on the surface. Cut the strip into pieces sufficiently small to be put into a small mercury bulb tube, and heat in spirit lamp flame, excluding air from the tube by the forefinger: the arsenic sublimes, leaving the copper clean, and forms a grey film in the tube; on re-subliming with access of air, white octohedral crystals of $As_2O_3$ are formed.

## EXERCISE XXIX.

# RARER METALS.

### SOLUTION OF URANIC NITRATE.

To a portion of the solution add—

1. HCl.: no ppt.; then
2. $H_2S$: no ppt.

To other portions of the solution add—

3. $NH_4HO$: yellow ppt. of $(NH_4)_2UO_4UO_3$; insoluble in excess, but soluble in $(NH_4)_2CO_3$.
4. $(NH_4)_2S$: brown ppt.; insoluble in excess; soluble in $(NH_4)_2CO_3$.
5. $(NH_4)_3PO_4$: white ppt. ($UO_2NH_4PO_4$); soluble in a large quantity of $NH_4HO$.
6. $K_4Cfy$.: red ppt.
7. $K_3Cfdy$.: no ppt.
8. Make borax bead: bead greenish in inner flame, yellowish-green in outer flame.

### SOLUTION OF CERIUM CHLORIDE.

Add—

1. HCl: no ppt.
2. $H_2S$: no ppt.
3. $NH_4HO$: white ppt.; insoluble in excess, in NaHO, $(NH_4)_2S$, and $(NH_4)_2CO_3$; soluble in $HC_2H_3O_2$.
4. $H_2C_2O_4$: white ppt.; insoluble in HCl and converted by roasting in air into red $CeO_2$.
5. NaClO, and boil: yellow or red ppt.
6. Make borax bead: red when hot, colourless when cold.

### SOLUTION OF SODIUM TUNGSTATE.

To portion of the solution add—

1. HCl: white ppt ; insoluble in excess, soluble in $NH_4HO$ and NaHO.
2. $H_2S$: no ppt. either with acid or alkaline solution; but if the solution of $Na_2WO_4$ is either saturated with $H_2S$ or treated with $(NH_4)_2S$, on adding HCl a brown ppt. falls, soluble in $(NH_4)_2S$ and in NaHO.
3. Add HCl and zinc: a blue ppt. of $W_2O_5$, afterwards becoming brown $WO_2$.
4. Add $SnCl_2$: white ppt. of $H_2WO_4$ in the cold; but on heating blue ppt. of $W_2O_5$.
5. Add $K_4Cfy$, then HCl: brown ppt.

### SOLUTION OF AMMONIUM MOLYBDATE.

To the solution add—

HCl: white ppt.; soluble either in excess of HCl or in $NH_4HO$.

To a portion of the hydrochloric solution add—

1. $H_2S$: brown ppt. The $MoS_2$ falls with difficulty in this way. It is better to add $(NH_4)_2S$ to an ammonical solution of the acid, and precipitate by adding HCl.
   Filter the brown ppt. and wash, then add $(NH_4)_2S$: ppt. dissolves.
2. To a portion of the HCl solution add zinc: the liquid becomes first blue, then green, and finally black.
3. To a portion of a nearly neutral solution add $SnCl_2$ gradually: a blue ppt.
4. Evaporate a portion of any molybdic solution to dryness with $H_2SO_4$; when just dry breathe on the residue to enable it to absorb moisture: a blue colour is produced.
5. Make borax bead: in the inner flame a brownish coloured bead, and in the outer flame a yellow bead.
6. Place a small portion of the ppt. caused by HCl in a colourless Bunsen flame: yellowish-green flame.

### SOLUTION OF VANADIUM CHLORIDE.

To a portion of the solution add—

1. HCl: no ppt.; then
2. $H_2S$: solution becomes blue, and sulphur is precipitated.
3. To other portions add $H_2SO_3$: the solution becomes blue by the formation of $V_2O_2Cl_4$.
4. $(NH_4)HO$ or NaHO, and saturate the solution with $NH_4Cl$: white ppt. of $(NH_4)_3VO_4$.
5. To a solution of $H_3VO_4$ add $(NH_4)_2S$: brown solution; then add $H_2SO_4$: brown ppt. soluble in $(NH_4)_2S$.
6. To a small portion of a HCl solution add $K_4Cfy$.: green ppt.
7. To another portion add Gallic Acid; a blue-black colour.

### TITANIUM.

$TiO_2$ is soluble in boiling concentrated Sulphuric Acid, and is not precipitated on dilution; but by boiling the dilute sulphuric solution, $H_2TiO_3$ is precipitated.

Titanium is precipitated from its solutions like Alumina or Silica by $NH_4HO$ as a white gelatinous ppt., soluble in HCl, but rendered insoluble like $SiO_2$ by ignition.

Insoluble Titanates and $TiO_2$ are rendered soluble by fusion with $KHSO_4$. A solution acidulated by dilute $H_2SO_4$ deposits white $H_2TiO_3$ on prolonged boiling.

$TiO_2$ or $H_2TiO_3$ yields with microcosmic salt ($NaNH_4HPO_4$) in the inner blow-pipe flame a violet bead.

$TiO_2$ becomes soluble in HCl after fusion with Sodium Carbonate.

An acid solution of Titanium treated with Zinc or Tin is reduced to a salt of TiO, and becomes violet, but becomes again colourless on exposure to air.

A nearly neutral solution yields an orange ppt. with Tannic Acid.

# PRELIMINARY EXAMINATION

## OF SIMPLE SALTS AND MIXTURES.

*If the substance is a liquid, examine it by blue and red litmus papers; evaporate a portion to dryness and treat the residue as under. If the substance is solid, reduce it to fine powder, noting its physical characters.*

I. Heat a small portion of the substance on a clean platinum wire, either in the inner blow-pipe flame, or in a colourless Bunsen flame.

| | | | |
|---|---|---|---|
| The substance tinges | the flame | yellow . . . | **Sodium.** |
| " | " | violet . . . | **Potassium.** |
| " | " | olive-green . . | **Barium.** |
| " | " | yellow-green . | **Molybdenum.** |
| " | " | crimson . . . | **Strontium,** or **Lithium.** |
| " | " | red . . . . | **Calcium.** |
| " | " | green . . . | **Copper, Boric Acid; Thallium.** |
| " | " | blue . . . . | **Copper, Arsenic, Antimony,** or **Lead.** |

II. Heat a small portion of the finely pulverised substance in a glass tube.

*If the substance does not change,* organic matter, Hydrates, salts containing water of crystallization, fusible and volatile substances are all absent.

*a. The substance fuses and swells up, giving off steam.* Salts having water of crystallization, *e.g.*, Alum, Borax, &c., or Hydrates.

Test the reaction of the fluid condensed in the tube.

If alkaline, **Ammonia,** and if acid, **Volatile Acids** are present.

*β. The substance gives off gases or fumes—*

Oxygen (supports combustion) **Peroxides, Nitrates, Hypochlorites, Chlorates, Perchlorates, Bromates, Iodates,** &c.

Nitrous Oxide, $N_2O$ (supporting combustion) from **Ammonium Nitrate.**

Sulphurous Gas, $SO_2$ (odour), from **Sulphites,** and **Hyposulphites,** &c.

Nitric Peroxide, $N_2O_4$ (reddish-brown vapours), from the decomposition of **Nitrates.**

Nitrogen, from **Ammonium Nitrite, Ammonium Bichromate,** &c.

Carbonic Gas, $CO_2$ (precipitates lime water), from **Carbonates.**

Carbonous Oxide, $CO$ (burns with blue flame), from **Oxalates, Formates,** and other organic salts.

Cyanogen, $CN$ (odour, and peach-blossom coloured flame), from various **Cyanogen** compounds.

Carbon Disulphide, $CS_2$, from **Sulphocyanates.**

Chlorine, Bromine, or Iodine (recognized by their odour), from several of their compounds.

Hydrosulphuric Acid, $H_2S$ (odour, and blackens lead paper), from moist **Sulphides, Sulphites,** and **Hyposulphites.**

Ammonia, $NH_3$ (odour, and alkaline to test paper), from **Ammonium Salts** and some **Cyanogen** compounds.

γ. *The substance sublimes* into the cold part of the tube.

| | |
|---|---|
| In yellow drops of Sulphur . . . . | From **Sulphides** and free **Sulphur,** and **Hyposulphites.** |
| Yellow crystals . . . . . . . . . | **Mercuric Iodide,** or **Arsenious Sulphide.** |
| White sublimate, which evolves Ammonia when heated with Lime or Potash . . . . . . . . . . . | **Ammonium** Salts. |
| White crystalline sublimate, with heavy fumes. . . . . . . . . | **Mercurous** or **Mercuric Chloride.** |
| White octohedral crystals . . . . | **Arsenious Anhydride.** |
| White crystalline sublimate, with heavy, rather irritating fumes . . . . . | **Oxalic Acid.** |
| White sublimate fumes: cause violent coughing . . . . . . . . . . | **Succinic Acid.** |
| White, with odour of frankincense. . | **Benzoic Acid.** |
| Bluish-black crystals, violet fumes . . | **Iodine.** |
| Black, and becomes red on rubbing . | **Mercuric Sulphide.** |

δ. *Sublimate when heated with dry Sodium Carbonate* in a bulb tube, yields—

| | |
|---|---|
| A metallic mirror and globules. . . | **Mercury** compounds. |
| If $NH_3$ is given off . . . . . . | **Ammonium** compounds. |
| *Sublimate when heated with Black Flux, or with a mixture of Sodium Carbonate and Charcoal, or dry KCy,* in a bulb tube: yields a black shining deposit . . . . . . . . . . . | **Arsenic** compounds. |

ε. *The substance chars.* Presence of organic matter. The odour evolved frequently indicates the nature of the organic matter, *e.g.*—

| | |
|---|---|
| Acetone . . . . . . . . . . | **Acetates.** |
| Odour of burnt sugar, from . . . | **Tartaric Acid, Sugar,** &c. |
| Pungent odour. . . . . . . . | **Citric, Malic,** and other Acids. |
| Odour of burnt feathers . . . . | **Uric Acid.** |
| **Carbolic** Acid, **Fatty** Acids, **Naphthalin,** &c., &c. | |
| **Hydrocyanic** Acid. | |
| A Carbonate is left which effervesces with acids, although the original substance did not effervesce . . | **Organic Acids,** with a mineral base. |

ζ. *The substance changes colour—*

| | |
|---|---|
| To yellow while hot, white when cold | **Oxide of Zinc**, ZnO. |
| To yellowish-brown, dirty yellow when cold . . . . . . . . | **Oxide of Tin**, $SnO_2$. |
| To reddish-brown, yellow when cold | **Oxide of Lead**, PbO. |
| To orange-red, dull yellow when cold | **Oxide of Bismuth**, $Bi_2O_3$. |

III. Heat a portion of the substance on charcoal in the blow-pipe flame.

| | |
|---|---|
| It decrepitates . . . . . . . . . | Many Salts. |
| It deflagrates . . . . . . . . . . | **Nitrates, Chlorates, &c.** |
| It fuses and is absorbed . . . . . | **Alkaline** Salts. |
| The residue is white, infusible, and alkaline to test paper . . . . . | **Oxides** of **Barium, Strontium, Calcium,** or **Magnesium.** |
| The residue is white and luminous. . | **Alkaline Earths, Alumina, Zinc Oxide,** or **Silica.** |

α. Moisten the infusible residue with a drop of Cobalt Nitrate, and heat again in blow-pipe flame—

| | |
|---|---|
| A blue mass remains . . . . . . | **Alumina, Silicates,** or some **Phosphates.** |
| A pink mass „ . . . . . . | **Magnesia.** |
| A green mass „ . . . . . . | **Zinc Oxide.** |

$SnO_2$ gives a blue-green, and BaO a dirty green mass.

β. The residue is coloured. Heat a small portion in a clear Borax bead on platinum wire in the inner and outer blow-pipe flame—

| | | |
|---|---|---|
| Blue in the inner, | blue in the outer flame . . | **Cobalt.** |
| Red „ | blue „ . . | **Copper.** |
| Grey „ | red „ . . | **Nickel.** |
| Colourless „ | amethyst-red „ . . | **Manganese.** |
| Green „ | bottle-red „ . . | **Iron.** |
| Green „ | green „ . . | **Chromium.** |
| Dirty green „ | yellow „ . . | **Uranium.** |
| Brown „ | yellow „ . . | **Molybdenum.** |
| Red when hot, colourless when cold | . . . | **Cerium.** |

γ. The residue is metallic when the inner blow-pipe flame is used.

| | |
|---|---|
| Brilliant, hard, and malleable . . . . . . . | **Silver.** |
| Yellow „ „ . . . . . . . | **Gold.** |
| Red scales or globules . . . . . . . . . | **Copper.** |
| Soft and malleable . . . . . . . . . | **Lead.** |
| Brittle; no incrustation, or only a slight yellow deposit . . . . . . . . . . . . . . . | **Bismuth.** |
| Brittle: gives white fumes and white semi-transparent incrustation . . . . . . . . | **Antimony.** |

δ. The metal is reduced, but being volatile, passes through the outer flame and yields an incrustation—

| | |
|---|---|
| White, semi-transparent . . . . . . . . . | **Antimony.** |
| White with garlic odour . . . . . . . . . | **Arsenic.** |
| Yellow while hot, white on cooling . . . . . | **Zinc.** |
| Brown . . . . . . . . . . . . . . . . | **Cadmium.** |

ε. **Tin** requires the assistance of Potassium Cyanide to aid its reduction. The metal is bright and malleable. The slight incrustation is yellow when hot, white when cold.

Sodium Carbonate, $Na_2CO_3$ sometimes aids the reduction.

ζ. **Sulphur Acids** are reduced by fusion with $Na_2CO_3$ on charcoal in the inner blow-pipe flame. If the mass be placed on a bright surface of silver, and moistened, a black stain will be produced; or if the mass be acidulated, $H_2S$ will be evolved.

## IV. Heat with Hydrochloric Acid, HCl, in a test tube.

| | | |
|---|---|---|
| Effervescence. The evolved gas renders lime-water turbid, $CO_2$ | from | **Carbonates.** |
| The gas has odour of burning Sulphur, $SO_2$ | „ | **Sulphites.** |
| The same with separation of Sulphur | „ | **Hyposulphites.** |
| The gas has odour of rotten eggs, and blackens paper moistened with Lead Acetate, $H_2S$ | „ | **Sulphides.** |
| The same with precipitation of Sulphur | „ | **Polysulphides.** |
| Odour of Hydrocyanic Acid | „ | **Cyanides.** |
| The same with $CO_2$ | „ | **Cyanates.** |
| Reddish-brown fumes, $N_2O_3$ | „ | **Nitrites.** |
| Chlorine | „ | **Hypochlorites, Binoxides,** or **Chromates.** |
| Euchlorine | „ | **Chlorates,** &c. |

A jelly is formed; **Silica,** from **Silicates.**

Many acids are pptd. by HCl, *e.g.*, those mentioned in the first column, p. 25.

## V. Treat a portion of the substance with HCl and metallic zinc.

| | |
|---|---|
| A violet colour may be due to | **$TiO$.** |
| A blue „ „ | **$W_2O_5$.** |
| Afterwards brown | **$WO_2$.** |
| Blue, then green, then dark brown | **Mo.** |
| Green (orange before the addition of Zn) | **$Cr_2O_3$** |
| Brown (and indigo after the addition of starch paste) | **$HIO_3$.** |

**Before proceeding to the systematic examination of a substance, a solution must be prepared.**

1. If it is not a metal nor an alloy, dissolve it, or as much of it as will dissolve, in water; decant or filter, and treat the residue, if any, with Hydrochloric Acid ($HCl$), and boil; filter if necessary. The aqueous and hydrochloric solutions may be mixed and analysed together, or they may be analysed separately, if required.
2. Treat the residue insoluble in water and $HCl$, with Nitric Acid ($HNO_3$), and boil; treat any residue with aqua regia. The following substances only may remain at this stage: $BaSO_4$, $SrSO_4$, $CaSO_4$, $PbSO_4$, $AgCl$, $AgBr$, $AgI$, $HgI_2$ ignited sesquioxide earths and their compounds, siliceous substances, titanates, $SnO_2$, $Sb_2O_4$, $CaF_2$, metaphosphates, and arsenates, sulphur, carbon, and some ores.
3. Any residue, insoluble in water and acids, must be dried, mixed with four times its weight of dry Alkaline Carbonates ($K_2CO_3$, and $Na_2CO_3$), and fused in a crucible. Boil the fused mass with water, and filter; examine the filtrate for acids; dissolve the insoluble portion (which contains the bases, in the form of Carbonates) in $HCl$, and examine the solution separately.
4. Cyanogen compounds should be fused in a porcelain crucible, with an equal weight of $(NH_4)NO_3$, and three times their weight of $(NH_4)_2SO_4$; the metals can then be detected in the usual way.
5. If the substance is a *metal* or *alloy*, observe its physical characters, and reduce it to thin sheets or filings; then—

   *a.* Heat a small portion with water and Acetic Acid; Hydrogen is evolved; presence of Na, K or Mg. Examine the solution by table for Group VI.

   *b.* Heat a portion in a glass tube, sealed at one end. A sublimate indicates Hg, As, or Cd.

   *c.* Dissolve in $HNO_3$. and dilute with water.

      ($\alpha$) The metal dissolves with evolution of red fumes. Presence of Ag. Hg, Pb, Bi, Cu, Cd, As, Fe, or Zn. Examine the solution in the usual way.

      ($\beta$) Red fumes are evolved, but a white powder remains insoluble. Presence of Sn or Sb. If no other metals are present, a fresh portion may be dissolved in $HCl$, and the solution examined by $H_2S$, and by $HgCl_2$, for Sb and Sn. If other metals are present, collect the white insoluble oxides and fuse with Hydrate of Soda in a silver crucible; treat the cooled mass with water, and add one-third of its volume of Alcohol; filter.

| | |
|---|---|
| Acidulate the filtrate with $HCl$, and examine the solution for Sn, and for As which may have accompanied it. | Dissolve the residue of Sodium Metantimonate in $HCl$, and examine the solution for Sb. |

   *d.* If the metal is unchanged by $HNO_3$, boil with $HCl$. Al dissolves readily. (Sn or Sb are dissolved by prolonged boiling with $HCl$.)

   *e.* If a metal still remains unchanged, dissolve in Nitro-hydrochloric Acid (Aqua Regia), and test for Au by $FeSO_4$, or $SnCl_2$ and for Pt, by $NH_4Cl$.

## TABLE FOR THE SEPARATION OF METALS INTO GROUPS.

* To the greater portion of the solution, add **HCl** in excess and filter.

<table>
<tr>
<td rowspan="5">The ppt. may contain<br>**$PbCl_2$** white.<br>**$AgCl$** white.<br>**$Hg_2Cl_2$** white.<br><br>Group I.<br>p. 27.<br><br>Oxychlorides may be pptd., but will redissolve in more acid.<br>The following may also be pptd. from alkaline solutions, but will be dissolved (after filtration) by caustic alkalies.<br><br>$H_4SiO_4$ gelatinous.<br>$H_3BO_3$<br>Benzoic and Uric acids.<br>$Sb_2O_5$, $WO_3$, $MoO_3$<br>$As_2S_3$<br>$Sb_2S_3$<br>$Sb_2S_5$<br>$SnS$<br>$SnS_2$<br>See also preliminary examination, p. 23.</td>
<td colspan="5">Dilute the filtrate with $H_2S$ water, saturate it with **$H_2S$** gas, heat gently and filter. $H_2S$ should be again passed through the filtrate to ascertain whether all the metals of Group II have been pptd.</td>
</tr>
<tr>
<td rowspan="4">A white ppt. or milkiness may be only sulphur.†<br>The ppt. may contain<br><br>Insoluble in alkaline sulphides.<br>**$PbS$** black.<br>**$HgS$** black.<br>**$CuS$** black.<br>**$Bi_2S_3$** black.<br>**$CdS$** yellow.<br><br>Soluble in alkaline sulphides.<br>**$SnS$** brown.<br>**$SnS_2$** yellow.<br>**$Sb_2S_3$** orange.<br>**$As_2S_3$** yellow.<br>**$Au_2S_3$** black.<br>**$PtS_2$** brown.<br>**$MoS_3$** brown.<br><br>Group II.<br>p. 28.<br><br>[Se red.<br>Te black.]</td>
<td colspan="4">If Groups I and II have been found to be absent (and if no organic matter be present), take a fresh portion of the original solution and proceed as at ‡; if not, evaporate the filtrate to dryness; if organic matter is present, heat the residue to redness, but not otherwise. Add a little conc. HCl and $HNO_3$, then dilute with water, and heat until only a white residue of silica and $TiO_2$ remains.<br>‡ Take a few drops of the solution in each of two watch glasses; test one by a drop of (Potassium Ferrocyanide) $K_4Cfy$ for Ferric Salts, and the other by a drop of (Potassium Ferricyanide) $K_3Cfdy$ for Ferrous Salts; if the latter are present, the solution must be boiled with gradual addition of $HNO_3$, until the Ferrous Salts have been completely converted into Ferric Salts. If insufficient HCl or $HNO_3$ has been added to form ammonium salts in order to keep Group IV and Mg in solution, add sufficient $NH_4Cl$, then precipitate by excess of **$NH_4HO$**, heat and filter.</td>
</tr>
<tr>
<td rowspan="3">Ppt. may contain<br>**$AlH_3O_3$** white.<br>**$FeH_3O_3$** red.<br>**$CrH_3O_3$** green.<br>**$AlPO_4$** white<br>and Phosphates (Borates, Oxalates, and Fluorides) of the Alkaline Earths, white.<br>$(NH_4)_2UO_4UO_3$ yellow.<br><br>Group III.<br>p. 29.<br><br>A basic Cerium Salt may also be precipitated here.</td>
<td colspan="3">To the filtrate add slight excess of **$(NH_4)_2S$**, or pass $H_2S$ gas through the alkaline solution and filter.</td>
</tr>
<tr>
<td rowspan="2">Ppt. may contain<br>**$NiS$** black.<br>**$CoS$** black.<br>**$ZnS$** white.<br>**$MnS$** flesh-coloured.<br><br>Group IV.<br>p. 30.</td>
<td colspan="2">To filtrate add $NH_4Cl$, if it is not already present, and **$(NH_4)_2CO_3$**; do not boil, but filter cold.</td>
</tr>
<tr>
<td>Ppt. may contain<br>**$BaCO_3$**<br>**$SrCO_3$**<br>**$CaCO_3$**<br><br>Group V.<br>p. 31.</td>
<td>The filtrate may contain salts of<br>**Mg.**<br>**Li.**<br>**K.**<br>**Na.**<br>**$NH_4$**<br>Group VI.<br>p. 32.</td>
</tr>
</table>

* Test a portion of the solution first for ammonium salts.

† By the oxidizing action of Cl, Br, I, $SO_2$, and the oxygen acids of N, Cl, Br, F, Sulphur may be pptd. from $H_2S$. Ferric Salts will be rendered colourless, and chromates will be rendered green by $H_2S$, with separation of sulphur.

## NOTES ON THE RARER METALS.

Tungsten is pptd. in Group I, and may be obtained along with other acids and silver chloride by digesting with ammonia: on filtering, reprecipitating from the solution by HCl, and dissolving in excess of HCl, the tungstic acid remains insoluble; filter, suspend the ppt. in HCl, and treat with metallic zinc. Test also by the microcosmic salt bead with tin, in the inner blow-pipe flame.

2. Molybdenum is found in Group II, along with $SnS_2$ when reprecipitated from the alkaline solution by HCl (p. 28); it may be separated by ignition (which converts the sulphides into oxides), and solution in $NH_4HO$; or better, it may be obtained from the HCl ppt., Group I, by avoiding excess of HCl, digesting with ammonia, filtering, reprecipitating by HCl, and dissolving in excess of HCl. Molybdenum may be then recognized by the Zn and HCl test, by the borax bead, and by the coloured flame.

3. Uranium may be separated from Group III ppt. after testing for phosphates (and before redissolving for precipitation by NaHO), by digesting in $(NH_4)_2CO_3$, in which the uranium dissolves; filter, and examine the filtrate by the tests given on p. 17.

4. Cerium is found in Group III, along with the phosphates of the alkaline earths. See p. 29.

5. Titanium is found along with silica, or in Group III.

## GROUP I.

*The ppt. may contain $PbCl_2$, $AgCl$, $Hg_2Cl_2$.**

| Wash the ppt. on the filter paper with a large quantity of hot water, till it is quite free from $PbCl_2$. | | |
|---|---|---|
| The filtrate may contain<br>**$PbCl_2$.**<br>Confirm by adding a few drops of $K_2CrO_4$, yellow ppt.,<br>or $H_2SO_4$, white ppt.,<br>or KI, yellow ppt. when cold. | The white residue may contain AgCl, $Hg_2Cl_2$. Add excess of $NH_4HO$, and filter. | |
| | Solution may contain $\left.\begin{matrix}H_3\\Ag\end{matrix}\right\}NCl$.<br>Confirm by adding $HNO_3$ to the ammoniacal solution till the liquid shows an acid reaction. A white curdy ppt. of AgCl shows the presence of **Ag.** | Residue is now black and consists of $\left.\begin{matrix}H_4\\Hg_4\end{matrix}\right\}N_2Cl_2$.<br>Confirm.<br>Dry some of the black residue and mix with dry $Na_2CO_3$, and heat in a bulb tube.<br>A metallic mirror or globules indicate **$Hg_2$ Mercurosum.** |

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* Unless HCl has been added in sufficient excess, and the solution gently heated, certain Oxychlorides of Bi, Sb and Sn may have been precipitated in this group; also the substances mentioned on p. 25.

## GROUP II.

*The ppt. may contain PbS, HgS, CuS, CdS, $Bi_2S_3$, $SnS_2$, SnS, $Sb_2S_3$, $As_2S_3$. Au, Pt and Mo must be specially tested for in separate portions of the filtrate from Group I.* Wash well until the filtrate is free from HCl. Transfer to a flask or tube, and boil with yellow $(NH_4)_2S_2$ or NaHO, and filter.

<table>
<tr><td colspan="5">Residue may consist of PbS, HgS, $Bi_2S_3$, CuS, CdS. Wash well, and boil in conc. Nitric Acid until all action ceases; add a few drops of dilute $H_2SO_4$ as long as a ppt. of $PbSO_4$ falls; allow to stand, and then filter (addition of alcohol alone ensures the complete precipitation of lead sulphate).</td><td colspan="3">To the filtrate add HCl to acid reaction, then $H_2S$, yellow ppt. Agitate the ppt. with stale $NH_4HCO_3$ in the cold for ten minutes, and filter.</td></tr>
<tr><td colspan="2" rowspan="2">Residue of HgS, black, trace of $PbSO_4$, white, and S.<br>Boil white ppt., if any, in Ammonium Tartrate or Ammonium Acetate; allow to cool; filter.</td><td colspan="3">Solution may contain Bi, Cu, Cd. Add excess of Ammonia; boil and filter.</td><td rowspan="3">Filtrate may contain $As_2S_3$; add HCl. A yellow ppt. indicates <b>As.</b> Dry and test by reduction with $Na_2CO_3$ and KCy in a bulb tube. Metallic mirror of <b>Arsenic.</b></td><td colspan="2">Residue may contain Sn and Sb as sulphides: dissolve in HCl aided by a few drops of $HNO_3$, and pour the solution into a small Hydrogen apparatus containing pure zinc and dilute $H_2SO_4$.*</td></tr>
<tr><td rowspan="2">Ppt. may be $BiH_3O_3$; dissolve in HCl; evaporate just to dryness, and add water; a cloud or milkiness indicates<br><b>Bi.</b></td><td colspan="2">Solution may contain Cu, Cd. A blue colour indicates copper. In order to detect Cd in presence of Cu, add KCy until the solution is colourless; then $H_2S$.</td><td rowspan="2">$SbH_3$ gas comes off; burn the gas and collect the metal on a cold porcelain plate; add NaClO to the stains; no change indicates<br><b>Sb.</b></td><td rowspan="2"><b>Tin,</b> if present, will be precipitated on the zinc. Detach a portion; dissolve in HCl, and test by means of $HgCl_2$, and by the blow-pipe.</td></tr>
<tr><td>Black residue, HgS; confirm by reduction with $Na_2CO_3$ in a bulb tube.<br>Globules of<br><b>Hg</b><br><b>Mercuricum.</b></td><td>To solution add $K_2CrO_4$, yellow ppt. indicates<br><b>Pb.</b></td><td>Ppt. is yellow, CdS, presence of<br><b>Cd.</b></td><td>Filtrate; boil with dilute $HNO_3$; add Ammonium Acetate and $K_4Cfy$; red ppt. indicates<br><b>Cu.</b></td></tr>
</table>

* Or the Hydrochloric solution may be placed in a platinum dish; if a rod of zinc be then introduced into the liquid, so as to touch the platinum outside the liquid only, a brown film of metallic **Antimony** will rapidly adhere closely to the platinum, while **Tin** will be reduced in the form of a fine powder.

## GROUP III.

NOTE 1. *It is well to test a small portion of the ppt. for Phosphates by Ammonium Nitro-Molybdate; if no yellow ppt. falls on heating, all that portion of the manipulation which refers to the separation of Phosphates (indicated by italics) may be omitted in this table.*

NOTE 2. Uranium may be separated at this stage. (*See* p. 26.)

The ppt. may contain Al, Cr, Fe, and *Phosphates;* wash well, until no trace of Ammonia remains; then dissolve in as small a quantity as possible of HCl;* add NaHO in excess, and filter.

<table>
<tr>
<td colspan="3">Filtrate may contain $AlH_3O_3$, $CrH_3O_3$ and *$AlPO_4$*.<br>If green boil for some time, and filter.</td>
<td colspan="3">Ppt. may contain $FeH_3O_3$, with possibly part of the $CrH_3O_3$, *and Phosphates.* (Test a portion for Cr by fusion with $KNO_3$ and $Na_2CO_3$ on Platinum foil.) *Digest with Acetic Acid.*</td>
</tr>
<tr>
<td rowspan="2">Ppt. green is $Cr_2O_3$.<br>Confirm by fusion with $KNO_3$, and $Na_2CO_3$ on Platinum foil.<br>A yellow mass indicates<br>**Cr.**</td>
<td colspan="2">Filtrate may contain $AlH_3O_3$ and *$AlPO_4$. Add Acetic Acid in slight excess, and filter if necessary.*</td>
<td rowspan="2">*Residue is reddish-white*<br>**$FePO_4$.**</td>
<td colspan="2">*To the solution add Citric Acid and excess of Ammonia; filter if necessary.*</td>
</tr>
<tr>
<td>*Ppt. is*<br>**$AlPO_4$.**</td>
<td>*To filtrate* add Ammonia.<br>A white gelatinous ppt. is<br>**$AlH_3O_3$.**</td>
<td>*A white ppt. indicates an* **Alkaline-earthy Phosphates.**<br>†*Dissolve in HCl; add Potassium Acetate and $Fe_2Cl_6$ until the liquid becomes distinctly red; boil until it has lost its red colour; filter, and examine the filtrate for Alkaline earths.* See Groups V and VI.</td>
<td>Add to filtrate HCl and $K_4Cfy$.<br>A blue ppt. indicates **Fe,** *other than Phosphate.*<br>(Ferric and Ferrous Iron must be distinguished in the original solution.)</td>
</tr>
</table>

* Cerium may be pptd. from the HCl solution by adding Oxalic Acid, filtering, and igniting the ppt. The red binoxide may be dissolved in HCl with evolution of Cl, and the solution tested as on p. 17.

† *Or, dissolve in Acetic Acid, and test for Ca by $(NH_4)_2C_2O_4$ (white ppt.); filter, and test for Mg by $NH_4HO$ (crystalline ppt.).*

## GROUP IV.

Boil the ppt. of Sulphides as quickly as possible with Acetic Acid, and filter.

<table>
<tr>
<td rowspan="3">Filtrate contains Manganese Acetate.<br>Evaporate to dryness, and fuse on Platinum foil with $KNO_3$ and $Na_2CO_3$; a green mass indicates<br><b>Mn.</b></td>
<td colspan="3">Residue, if white, is ZnS; if black, it may also contain NiS, CoS. Dissolve in the least possible quantity of $HNO_3$; add NaHO in excess, and filter.</td>
</tr>
<tr>
<td rowspan="2">Filtrate contains<br><b>Oxide of Zinc.</b><br>Pass a current of $H_2S$ through the solution, or add $(NH_4)_2S$. A white ppt. indicates<br><b>Zn.</b><br><i>See preliminary examination.</i></td>
<td colspan="2">Dissolve the Precipitate in HCl; add a small quantity of $KClO_3$ (Potassium Chlorate), heat until all odour of Euchlorine disappears, nearly neutralize the solution with $Na_2CO_3$, add KCy sufficient to redissolve the precipitate first produced, and no more, boil for some time, and, if clear, add a strong solution of NaClO (Sodium Hypochlorite); allow to stand for some time, and filter.</td>
</tr>
<tr>
<td>A black ppt. indicates<br><b>Ni.</b><br>Confirm by Borax bead.</td>
<td>The solution may contain $K_3CoCy_6$.<br>Evaporate the filtrate to dryness, and test the residue by Borax bead.<br>A blue bead indicates<br><b>Co.</b></td>
</tr>
</table>

## GROUP V.

*The white ppt. may consist of Barium, Strontium, and Calcium, as Carbonates.*

Dissolve off the filter in the smallest possible quantity of Hydrochloric Acid, and dilute largely with water; divide into several portions.

| | | |
|---|---|---|
| To one portion add (Calcium Sulphate) $CaSO_4$, or very dilute $H_2SO_4$. An immediate ppt. indicates<br>**Ba.**<br>Ppt. after some time indicates<br>**Sr.**<br>Confirm the presence of Ba by the blow-pipe flame, and by $K_2CrO_4$ or by $H_2SiF_6$. | If Ba or Sr are present, add dilute $H_2SO_4$ to another portion, and filter; if these are absent omit the addition of $H_2SO_4$, neutralize the solution with $NH_4HO$, and add (Ammonium Oxalate) $(NH_4)_2C_2O_4$.<br>An immediate white ppt. indicates<br>**Ca.** | Examine another portion by flame of Bunsen burner or a colourless blow-pipe flame.<br>A green flame indicates **Ba.**<br>A crimson „ **Sr.**<br>A red „ **Ca.**<br>Confirm by spectroscopic examination of the flame. |

Or, the three Chlorides may be evaporated to dryness, $SrCl_2$ and $CaCl_2$ dissolved in strong Alcohol, and the residue tested for **Ba**. The solution may be freed from Alcohol by evaporation, treated with $H_2SO_4$, and filtered, and the ppt. boiled in concentrated solution of $(NH_4)_2SO_4$. The ppt. may be tested for **Sr** and the filtrate for **Ca.**

## GROUP VI.

*The Solution may contain Magnesium and the Alkaline metals.*

| I. | II. | |
|---|---|---|
| To a small portion of the solution, concentrated if necessary, add $NH_4HO$ and $(NH_4)_2PO_4$. A white crystalline ppt. indicates **Mg.** | **Evaporate** a larger portion to dryness, and ignite until fumes of Ammoniacal Salts cease to be evolved.*<br>Dissolve a portion of the residue in water, decant the clear solution into a watch glass, and add HCl and $PtCl_4$.<br>A yellow crystalline ppt. indicates **K.**<br>Examine a portion in the flame of Bunsen's burner.<br>A yellow flame indicates **Na.**<br>A violet „ „ **K.**<br>A crimson „ „ **Li.**<br>Confirm by a spectroscopic examination of the flame. | Test for $NH_4HO$ in a fresh portion of the original solution by Nessler's test, or by heating it with CaO or NaHO; the odour, or the power of changing red litmus paper blue when held over the mouth of the tube, indicates **$NH_4$.** |

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* If Lithium is to be looked for, the residue after ignition must be treated with a drop of HCl, and digested with a mixture of Ether and absolute Alcohol. The solution will burn with a crimson flame if **Li** is present.

## PRELIMINARY EXAMINATION FOR ACIDS.

Many acids have already been detected in the Preliminary Examination, pp. 20 to 23; and a few, *e.g.*, Silicic, Arsenious, Phosphoric, &c., during the examination for bases. See especially results of treating with HCl, p. 23, and Examination for Organic Acids, p. 21.

Before commencing the examination for acids, it is necessary to consider the solubility or non-solubility of the substance in water and in acids, and what acids can be present with the bases which have already been found. Thus, if the substance is soluble in water, carbonates of the alkaline earths and higher metals cannot be present, nor can any other acid forming insoluble salts with any of the bases found. If the substance is insoluble in both water and acids, no substances except those mentioned, p. 24, paragraph 2, can be present.

## EXAMINATION FOR MINERAL ACIDS.

The presence of bases often interferes with the detection of acids; in such cases, the bases may be removed in the following manner:—

Test first a small portion of the substance for $CO_2$ by adding HCl, and holding a rod moistened with lime water in the gas evolved, if any.

Test next for Nitric and Nitrous Acids by taking a small portion of the soluble portion of the substance in a test tube, adding a crystal of $FeSO_4,7H_2O$ (Ferrous Sulphate) and several drops of Sulphuric Acid: a brown solution round the crystals indicates $N_2O_2$, from **Nitrates or Nitrites.**

Then boil a larger quantity of the substance with the least possible excess of $Na_2CO_3$ and filter. Carefully neutralize the filtrate by the cautious addition of $HNO_3$, drop by drop, removing the $CO_2$ by boiling.

I. Having prepared a clear and neutral solution, add (Barium Chloride) $BaCl_2$, or (Barium Nitrate) $Ba2NO_3$: a ppt. may be formed. The following acids form Barium Salts, insoluble in water:—

**Sulphuric**: white. [Also **Selenic** and **Fluosilicic**].
**Carbonic** „
**Silicic** „
**Boric** „
**Phosphoric, Meta- Pyro- Ortho-**: white.
**Hydrofluoric**: white.
**Chromic**: yellow.
**Iodic**: white.
[**Phosphorous**: white.]
**Oxalic** and other organic acids, see p. 42, V.

To the ppt. add $HNO_3$; if any portion remains undissolved, add water; if it is still insoluble, **Sulphuric Acid** [Selenic, Fluosilicic] is present; if any portion dissolves with effervescence, $CO_2$ may be present, as well as some of the other acids of this group. If any portion dissolves without effervescence, some of the other acids are present.

II. To another portion of the neutral solution add (Silver Nitrate) $AgNO_3$; if a ppt. is formed, add $HNO_3$; if any portion dissolves, some of the following may be present:—

**Carbonic**: white ppt.; soluble in $HNO_3$, with effervescence.
**Boric**: white.
**Phosphoric**: yellow.
**Meta- and Pyro-Phosphoric**: white.
**Hypophosphorous**: white in the cold, then black on standing or on heating.
**Silicic**: white.
**Chromic**: red.
**Iodic**: white; soluble in strong, not in dilute, $HNO_3$.
[**Nitrous, Chlorous, Bromic, Hypochlorous, Hypobromous.**]
**Oxalic** and some other organic acids.

Each of these ppts. is soluble in Ammonia as well as in Nitric Acid.

If a portion of the ppt. remains insoluble in Nitric Acid, any of the following may be present:—

**Hydrochloric**: white curdy ppt.; soluble in Ammonia.
**Hydrocyanic** and other cyanogen acids: white curdy ppt., soluble in Ammonia; decomposed and Silver reduced when strongly ignited.
**Hydrobromic**: yellowish-white; slightly soluble in Ammonia.
**Hydriodic**: pale yellow; insoluble in Ammonia.
**Hydrosulphuric**: black; „

N.B.—**Free Sulphurous, Hyposulphurous, Phosphorous,** and **Hypophosphorous Acids,** Ferrous Salts, and many organic acids produce black precipitates of reduced Silver when heated with $AgNO_3$.

[Hypochlorites and Hypobromites bleach litmus paper.]

III. The following salts are not precipitated by the Barium salt nor by the Silver salt. Heat a portion of the solution with a drop of a solution of Indigo sufficient to tinge the solution blue, and a few drops of strong pure Sulphuric Acid; the blue colour is discharged by **Nitrates, Chlorates, Perchlorates, Manganates** and **Permanganates.** [Peroxides act in a similar manner.]

N.B.—**Nitrites, Chlorites, Hypochlorites, Hypobromites,** and **Hypo-iodites** also decolorise Indigo, but they are precipitated by $AgNO_3$. **Chromates** and **Iodates** decolorise Indigo, but they are precipitated by $BaCl_2$ and by $AgNO_3$.

## SPECIAL TESTS FOR MINERAL ACIDS.

Salts of **Sulphur Acids** are detected by fusion with $Na_2CO_3$ on charcoal in the inner blow-pipe flame; if the mass is placed on a bright surface of silver, and moistened, a black stain will be produced; or, if the mass is acidulated, $H_2S$ will be evolved.

### SULPHURIC ACID.

To portions of a neutral solution add—

1. $BaCl_2$: finely pulverulent white ppt. of $BaSO_4$, insoluble in $HNO_3$ and in $NH_4HO$.
2. $Pb2C_2H_3O_2$: heavy white ppt. of $PbSO_4$, insoluble in dilute $HNO_3$; soluble in boiling concentrated HCl.

### SULPHUROUS ACID.

To portions of a neutral solution add—

1. $BaCl_2$: white ppt.; soluble in acids, but converted by $HNO_3$ into insoluble $BaSO_4$.
2. HCl: $SO_2$ gas evolved, but no $H_2S$; and sulphur is not pptd.
3. $AgNO_3$, and a drop of $H_2SO_4$: metallic silver reduced, especially on warming.
4. $Fe_2Cl_6$, HCl, and $K_3Cfdy$: blue ppt., by reduction of Prussian blue.

### HYPOSULPHUROUS ACID.

To portions of a neutral solution add—

1. HCl or $H_2SO_4$, and heat: $SO_2$ is evolved and sulphur is deposited.
2. $BaCl_2$: white ppt.; soluble in much water, decomposed by HCl as in (1).
3. $AgNO_3$: white ppt.; soluble in excess of Sodium Hyposulphite; precipitate when boiled deposits black $Ag_2S$.

### CARBONIC ACID.

To portions of the solution add—

1. $BaCl_2$: white ppt.; soluble in acids with effervescence of a nearly inodorous gas, $CO_2$, which renders lime water turbid.
2. Lime water or Baryta water: white ppt. of $CaCO_3$ or $BaCO_3$; soluble in HCl or $HNO_3$ with effervescence.
3. $AgNO_3$: white ppt.; soluble in $HNO_3$, with effervescence of $CO_2$.

**Silicic Acid** is detected in the examination for bases.

From a soluble salt the gelatinous $H_4SiO_4$ is precipitated by HCl, and on evaporation to dryness and ignition $SiO_2$ is

**formed, which is not soluble when again treated with HCl. It is soluble only in HF, or by fusion with alkali.**

### BORIC ACID.

To portions of a solution of the sodium salt add—

1. HCl: white scales of $HBO_2$ are pptd. if the solution is a concentrated one.
2. $BaCl_2$: white ppt.; soluble in acids.
3. $AgNO_3$: white ppt. if added to a concentrated solution; soluble in $HNO_3$ and in $NH_4HO$.
4. Slightly acidulate with HCl, and dip a strip of turmeric paper into the solution, then dry the strip at 212° Fh.; compare the red tint produced with the tint produced by HCl alone.
5. Acidulate with $H_2SO_4$, and dissolve in Alcohol. When the Alcohol is now burnt, Boric Acid imparts a green tinge to the edge of the flame.

### PHOSPHORIC ACID.

To a solution of the sodium salt add—

1. $BaCl_2$: white ppt.; soluble in $HNO_3$ and in HCl.
2. $CaCl_2$: white ppt. ($Ca_32PO_4$); soluble in $HC_2H_3O_2$.
3. $MgSO_4$ + $NH_4Cl$, + $NH_4HO$: white crystalline ppt. on stirring ($MgNH_4PO_4,6H_2O$).
4. $AgNO_3$: yellow ppt. ($Ag_3PO_4$); soluble in $HNO_3$, and in $NH_4HO$.
5. Solution of $(NH_4)_2MoO_4$ in $HNO_3$, in large excess and warm: yellow crystalline ppt.; insoluble in acids; soluble in $NH_4HO$.

Meta- and pyrophosphates give white ppts. with $AgNO_3$; both are converted into orthophosphates by fusion with alkaline carbonates.

Pyrophosphates precipitate $MgSO_4$; and metaphosphoric acid liberated from its sodium salt by acetic acid, coagulates egg albumen.

### HYDROFLUORIC ACID.

1. $BaCl_2$: gives a white ppt.; soluble in large quantities of $HNO_3$ or HCl.
2. $CaCl_2$: transparent gelatinous ppt.
3. $H_2SO_4$: conc. liberates HF, which etches glass.
4. $H_2SO_4$: with sand or powdered glass liberates gaseous $SiF_4$, which with moisture deposits gelatinous Silicic Acid.

### FLUOSILICIC ACID.

1. When evaporated on glass the acid, or its ammonium salt, evaporates completely, and etches the glass.
2. $BaCl_2$ gives a crystalline ppt.: $CaCl_2$, $SrCl_2$, and $Pb_2C_2H_3O_2$. do not give ppts.
3. KCl gives a gelatinous transparent ppt.

### CHROMIC ACID.

To portions of the neutral solution add—

1. HCl: red colour deepened; changed to green chromic salt by boiling with alcohol or by $H_2SO_3$.
2. HCl and $H_2S$: green solution and ppt. of sulphur.
3. $BaCl_2$: yellow ppt.; soluble in acids.
4. $AgNO_3$: red ppt.; soluble in $HNO_3$ and in $NH_4HO$.
5. $Pb2C_2H_3O_2$: yellow ppt.; soluble in dilute $HNO_3$, soluble in NaHO.
6. Peroxide of Hydrogen, Ether, and a drop of dilute acid shaken up together, yield a blue ethereal solution.

### IODIC ACID.

1. $BaCl_2$ gives a white ppt. of $Ba2IO_3$; soluble in $HNO_3$.
2. $AgNO_3$ gives a white ppt. of $AgIO_3$; sparingly soluble in $HNO_3$.
3. $H_2S$ gives Iodine, then HI, and Sulphur.
4. $H_2SO_3$: ppts. Iodine.

### PHOSPHOROUS ACID.

Resembles hypophosphorous acid in its reactions, except that phosphite of barium is insoluble in water; it also forms a lead salt, insoluble in water and in acetic acid.

### HYPOPHOSPHOROUS ACID.

1. Boiled with solution of NaHO, yields $Na_3PO_4$ and Hydrogen.
2. The dry salt when heated yields Pyrophosphate and $PH_3$.
3. The acid and its salts first ppt. and then decompose $AgNO_3$, yielding metallic silver.
4. Reduces solutions of Mercury and also of Gold.
5. With $CuSO_4$ in the cold, no change; but on adding one drop of $H_2SO_4$, and warming gently, a dark brown ppt. of $Cu_2H_2$ is formed, becoming metallic copper on heating.

### NITROUS ACID.

Sodium nitrite gives all the reactions of sodium nitrate, and in addition yields a white ppt. with $AgNO_3$, if not very dilute. Nitrites may be distinguished from nitrates (in the absence of hypochlorites, chlorates, bromine compounds, sulphurous acid, and hypophosphorous acid) by adding a few drops of a solution of rosaniline in strong acetic acid; the colour changes to blue, and is finally discharged by nitrites, and is not restored on dilution.

Pyrogallic acid, with a drop or two of $H_2SO_4$, makes the solution of nitrites brown; and starch paste, with KI and a drop of dilute $H_2SO_4$ gives the blue iodine reaction, even if the nitrite solution be very dilute.

### HYPOCHLOROUS ACID.

Besides the peculiar odour, the bleaching action on indigo, and the ppt. with $AgNO_3$, alkaline hypochlorite is recognized by forming a black peroxide with manganous salts and with nickelous salts. The free acid does not decolorise potassium permanganate.

### CHLOROUS ACID.

Chlorites resemble hypochlorites, but the acid decolorises potassium permanganate.

### HYDROCHLORIC ACID.

1. To a portion of the Sodium salt add $AgNO_3$: white curdy ppt., soluble in $NH_4HO$, insoluble in $HNO_3$; fusible without decomposition.
2. Heat another portion with $MnO_2$ and $H_2SO_4$: Chlorine is evolved; and may be recognized by its odour, and by its bleaching action on litmus.

### HYDROBROMIC ACID.

1. To a portion of the Sodium salt add $AgNO_3$: very pale yellow curdy ppt.; soluble with difficulty in $NH_4HO$, insoluble in $HNO_3$.
2. Heat another portion with concentrated $H_2SO_4$: vapour of Bromine is evolved.

### HYDRIODIC ACID.

To portions of the solution of the sodium salt add—

1. $AgNO_3$: pale yellow ppt.; insoluble in $NH_4HO$ and in $HNO_3$.
2. $Pb2C_2H_3O_2$: yellow ppt. in the cold.
3. $CuSO_4 + 2FeSO_4$: grey ppt.
4. Starch paste and Cl or $CaCl_2O_2$: blue ppt.
5. Heat with concentrated $H_2SO_4$: violet vapour of Iodine is evolved, which when cold colours starch paste deep blue.

### HYDROSULPHURIC ACID.

To portions of the sodium salt add—

1. $AgNO_3$: black ppt.
2. $Pb2C_2H_3O_2$: black ppt.
3. HCl: gas is evolved, which has the odour of $H_2S$, and blackens paper moistened with $Pb2C_2H_3O_2$.

4. Alkaline solutions give a purple tint with sodium nitroprusside: solutions of free $H_2S$ do not give this colour unless an alkali has been previously added.

### NITRIC ACID.

All the neutral salts are soluble.

To portions of a solution of sodium nitrate add—

1. Copper filings and $H_2SO_4$, and heat: red fumes of $N_2O_4$.
2. A crystal of $FeSO_4$ and a few drops of pure $H_2SO_4$: in a short time $N_2O_2$ is formed, and dissolved in the solution of Ferrous Sulphate, forming a dark ring or cloud round the crystal.
3. A small quantity of Brucia dissolved in concentrated $H_2SO_4$: a red tint is produced.

### CHLORIC ACID.

All the salts are soluble.

1. To a portion of the solution add $AgNO_3$: no ppt.
2. Evaporate a portion to dryness, and heat on charcoal: it deflagrates. Dissolve the residue in water (or dissolve a portion of the ignited salt in water), and add $AgNO_3$: white curdy ppt. of AgCl.
3. To another very small portion add $H_2SO_4$ or HCl: a greenish sweet smelling chlorinated gas is evolved.

### PERCHLORIC ACID.

Perchlorates resemble chlorates, but are not decomposed by $H_2SO_4$ in the cold.

## EXAMINATION OF ORGANIC COMPOUNDS.

Non-volatile organic substances are either charred when heated in an open glass tube, or with sulphuric acid in a test tube, or they evolve carbonic gas, which renders lime-water turbid.

Volatile organic substances give characteristic odours when thus heated.

Alkaloids and other nitrogenous organic substances yield ammonia when mixed with fused NaHO, or with soda-lime, and strongly heated. (If ammonia is evolved while yet cold, it probably comes from an ammonium salt.)

## ORGANIC ACIDS.

I. If the acid is liquid, evaporate the liquid to dryness, and heat the dry residue, if any. If the acid is solid, heat in an open dish or tube.

| | |
|---|---|
| Volatile, not blackened, emit characteristic odours— | |
| Acetous odour | **Acetic, Formic.** |
| Acetates give the odour of acetone. | |
| Aromatic odour | **Benzoic**, &c. |
| Very irritating odour | **Succinic.** |
| Butter odour. | **Butyric, Caproic**, &c. |
| Similar, but more offensive | **Valeric** and others. |
| Tar | **Phenic, Cresylic, Salicylic**, &c. |
| Peculiar and characteristic odours are emitted by | **Hydrocyanic** and other Acids. |
| Yield white sublimate and charred residue | **Malic, Meconic, Pyrogallic, Salicylic**, &c. |
| Yields a white sublimate and does not char unless impure | **Oxalic.** |
| Fuses and becomes black after some time | **Citric.** |

Char when heated in the dry state—

**Tartaric**, with odour resembling that of burnt sugar.
**Uric**, with odour of burnt feathers.
**Hippuric**, with odour like that of bitter almonds.
**Gallic, Tannic**, and many others.

II. Heat a portion of the dried substance in a test tube with conc. $H_2SO_4$.

Immediately blackened—

**Tartaric, Pyrogallic, Gallic, Tannic, Hippuric**, &c.

Blackened after some time—

**Citric, Malic, Uric, Meconic, Lactic,** &c.

Not blackened—

| | |
|---|---|
| Evolves CO, which burns with a blue flame | **Formic.** |
| „ $CO_2$ and CO . . . . . . . | **Oxalic.** |
| „ CSO, which burns with blue flame, and gives odour of $SO_2$ . . . | **Sulphocyanic.** |
| Evolve CO and form $(NH_4)_2SO_4$ . . . | **Hydrocyanic** and other **Cyanogen Acids.** |
| Volatile, and evolves pure CO . . . . | **Succinic.** |
| Volatile. . . . . . . . . . . . . | **Acetic, Benzoic,** &c., &c. |
| Heated with dilute $H_2SO_4$ the Cyanogen compounds evolve Hydrocyanic Acid (characteristic odour). | |

III. If the substance is an alkaline or neutral liquid, add HCl; or, if it is a solid insoluble in water and acids, but soluble in solution of NaHO, dissolve in NaHO and add HCl—

**Uric** is precipitated as a white powder.
**Benzoic** is precipitated as white flakes.
**Hippuric** „ „ feathers, insoluble in ether, soluble in boiling water.
**Stearic, Palmitic, Pinic,** and other fatty acids yield fatty precipitates, soluble in alcohol.

IV. Make a perfectly neutral solution by neutralizing the solution, if necessary, with sodium carbonate and add $AgNO_3$. The following are precipitated, and can be distinguished into two groups by $HNO_3$.

**Hydrocyanic:** white curdy ppt.; insoluble in $HNO_3$, soluble in $NH_4HO$ and in KCy. The ppt. when strongly ignited is decomposed into metallic silver.
**Sulphocyanic:** white ppt.; insoluble in $HNO_3$; soluble in $NH_4HO$.
**Ferrocyanic:** white ppt.; insoluble in $HNO_3$, soluble in $NH_4HO$.
**Ferricyanic:** orange ppt. „ „ „
**Meconic:** white ppt.; soluble in $HNO_3$, and in $NH_4HO$.
**Oxalic:** „ „ „
**Succinic:** „ „ „
**Benzoic:** „ „ „
**Salicylic:** „ „ „
**Tartaric:** „ „ „
**Citric:** „ „ „
**Malic:** „ „ „
**Acetic:** „ „ „ and others.
**Formic** and **Pyrogallic** reduce metallic silver.
Milk-sugar, and some other substances have a similar reducing action.
If **Tartrate** of silver be dissolved in the smallest possible quantity of Ammonia, and the solution warmed, a mirror of metallic silver is produced on the glass.
**Citrate** of Silver does not yield reduced silver in this manner.

V. To a partly neutralized but distinctly acid solution of vegetable acids, add (Calcium Chloride) $CaCl_2$, shake, and filter quickly without warming—

<table>
<tr><td colspan="2">Boil the ppt. (if any) in Acetic Acid.</td><td rowspan="2">Neutralize the filtrate partly with NaHO, finally with lime water, and heat to the boiling point; a white ppt. may contain<br><b>Citric.</b><br>Filter, and boil for a long time with addition of alcohol; a ppt. after prolonged boiling may contain<br><b>Malic.</b></td></tr>
<tr><td>A portion remaining undissolved in Acetic but soluble in HCl, may be<br><b>Oxalic.</b></td><td>The portion dissolved may contain<br><b>Tartaric.</b></td></tr>
</table>

**Meconate** of Calcium is also precipitated by $CaCl_2$.

To separate neutral salts of **Citric** and **Tartaric** Acids, the following is useful—

To the neutral solution add excess of $CaCl_2$, and filter after some time.
Calcium Citrate is insoluble in NaHO, but soluble in $NH_4Cl$.
Calcium Tartrate is soluble in cold NaHO, and reprecipitated on boiling.

VI. Prepare a neutral solution, and add (Ferric Chloride) $Fe_2Cl_6$.

The following give a red colour, but no ppt.:

**Acetic**: discharged by HCl, but not by $AgNO_3$.
**Formic** „ „ „
**Pyrogallic** „ „ (blue with $FeSO_4$).
**Sulphocyanic**: discharged by $HgCl_2$ (Mercuric Chloride), and by $AgNO_3$, but not by dilute HCl.
**Meconic**: not discharged by $HgCl_2$, nor by HCl.

The following give reactions:

**Salicylic**: violet solution.
**Carbolic** or **Phenic**: purple solution.
**Gallic** and **Tannic** give deep black solutions.
**Benzoic**, **Succinic**, and **Hippuric** give light red ppts.
**Ferrocyanic** gives Prussian blue in acid solutions.
**Ferricyanic** gives only a brown or green colour, reduced to a blue ppt. by $H_2SO_3$; and with Ferrous Salts it gives a deep blue ppt.

VII. Add KHO:

**Tartaric** gives white crystalline ppt. with acid solutions, or after addition of Acetic.
**Gallic** gives green, then red and brown colour.
**Tannic** gives brown.
**Pyrogallic** gives deep brown or black.

## SPECIAL TESTS.

**Uric Acid.** To the dry insoluble powder add a drop of Nitric Acid, and evaporate to dryness by a gentle heat; a red stain appears. When cold, add Ammonia; a purple solution of Murexide is produced.

**Tannic Acid** precipitates a solution of gelatine.

**Succinic Acid.** To a solution add $NH_4HO$, and $BaCl_2$: no ppt. Then add Alcohol: white ppt.

**Benzoic Acid** similarly treated gives no ppt.

**Hydrocyanic Acid.** 1. Add $FeSO_4$ and $Fe_2Cl_6$. If the solution is alkaline, the mixed Oxides of Iron only will be pptd.; but on addition of HCl, a Prussian blue ppt. will be formed. 2. Add a few drops of yellow Ammonium Sulphide, and evaporate to dryness. Dissolve in water, add $Fe_2Cl_6$, and filter if necessary: a blood-red solution is produced.

**Formic Acid:** reduces Gold, Silver, and Mercury from their salts, and also decolorises Potassium Permanganate.

**Acetic Acid:** heated with Alcohol and $H_2SO_4$ gives a characteristic odour of Acetic Ether.

**Carbolic Acid** or **Phenol** is distinguished by its odour when distilled with water acidulated by Sulphuric Acid. The distillate when treated with Hypochlorite of Calcium, and afterwards a few drops of Ammonia, gives a blue colour. The solution treated with Bromine gives yellow silky needles of Tribromophenol.

**Salicylic Acid** gives a similar reaction with Bromine.

**Lactic Acid** is a non-crystallisable syrupy liquid, soluble in water, alcohol, and in ether; heated with $H_2SO_4$ it chars and evolves CO gas; boiled with $HNO_3$ conc. it is converted into Oxalic Acid.

All its salts are soluble; and the crystals of Zinc Lactate are characteristic.

## BEHAVIOUR OF SOME NEUTRAL SUBSTANCES.

| | Heated in a Test Tube. | Heated with $H_2SO_4$. | Heated with NaHO. | Heated with Lead Acetate and $H_2SO_4$. |
|---|---|---|---|---|
| **Alcohol** | Volatile without blackening; vapour has odour, and is very combustible | Does not blacken. (Methylated Spirit becomes brown) | Behaves as when heated alone. (Methylated Spirit becomes brown) | Odour of Acetic Ether |
| **Amylic** Alcohol | Peculiar odour (soluble in Benzol) | Becomes red | — | Odour of Jargonelle pears |
| **Glycerine** | Decomposes without blackening, and emits acrid fumes | Emits acrid fumes | Behaves as when heated alone | Heated with Potassic solution of Copper Tartrate |
| **Sucrose** (Cane Sugar) | Chars, and gives odour of Caramel | Chars rapidly | Unaltered | Does not give precipitate of $Cu_2O$ |
| **Glucose** (Grape Sugar) | Chars | Chars slowly | Becomes dark brown | Gives a red precipitate of $5Cu_2O$ per $C_{12}$ |
| **Invert Sugar** | Chars | Chars slowly | Darkens | Gives precipitate of $5Cu_2O$ per $C_{12}$ |
| **Maltose** | Chars | Chars slowly | Darkens | Precipitate of $3Cu_2O$ per $C_{12}$ |
| **Lactose** (Sugar of Milk) | *Differs from the other Sugars in being insoluble in Alcohol*<br>Chars | Chars slowly | Gives brown solution slowly | Gives a red precipitate of $3\frac{1}{2}Cu_2O$ per $C_{12}$ |
| **Mannite** | Chars | Dark solution | Dark solution | Does not give a red precipitate of $Cu_2O$ |

**Gum** softens in cold water, gives no reaction with Tincture of Iodine, and is precipitated by tribasic Lead Acetate.

**Starch** consists of microscopic rounded grains, which polarise light; is insoluble in cold water, but forms a paste when boiled, and forms a deep blue compound with Tincture of Iodine.

**Dextrin** resembles starch in appearance, but softens like gum in cold water, and generally has an odour of rushes. Pure Dextrin does not give a blue compound with Iodine, but the commercial article (British Gum) does; is not precipitated by tribasic Lead Acetate, but is precipitated by Ammoniacal solution of Lead Acetate, and less perfectly by Alcohol.

Action on polarized light, and specific rotatory power of a solution of 16·34 parts of sugar in 100 parts of water, measured by the orange Sodium light:—

| | | |
|---|---|---|
| Sucrose | Right. | $S_D = +66\frac{1}{4}^{\circ}$ at 15° C. |
| Inverted Sugar | Left. | $S_D = -23$ „ 15° C. |
| Dextrose | Right. | $S_D = +52$ |
| Lævulose | Left. | $S_D = -98$ „ 15° C. |
| Maltose | Right. | $S_D = +139$<br>decreased by inversion. |
| Lactose | Right. | $S_D = +52\frac{1}{2}$ when old to<br>$+80$ „ fresh;<br>much increased by inversion. |
| Dextrin | Right. | $S_D = +193$ |
| Gum | Left. | |

# TABLE FOR THE SEPARATION OF ORGANIC BASES.

To a solution of the substance in water or dilute acid add NaHO, drop by drop, till the liquid has only a slightly alkaline reaction.

1. If oily drops are separated, which have an odour of **Aniline**; like that of mice, **Conine**; or of Tobacco, **Nicotine**,* these volatile liquid alkaloids may be separated by distillation in a small retort and receiver; or they may be dissolved in ether, the solution separated by a pipette, and the ether removed by evaporation; the characteristic tests may then be applied. Their Oxalates are soluble in Alcohol.
2. If the liquid gives no odour in the cold, but evolves Ammonia on boiling, **Urea** is probably present. If it gives the fishy odour of Methylamine, **Caffeine** may be present. Dissolve the original substance, rendered alkaline by NaHO, in Alcohol, filter and evaporate the filtrate to dryness, and apply special tests.
3. If NaHO gives no reaction, test the original substance for **Salicine.**
4. A white ppt. may be **Morphine, Quinine, Cinchonine, Narcotine, Codeine, Strychnine, Brucine, Veratrine, Atropine.** Add NaHO in excess, and filter. Dissolve any **Atropine** from the filtrate in Chloroform, and to the residue of the filtrate add $CO_2$ or $NaHCO_3$; evaporate to dryness, and dissolve in water; any residue which now remains insoluble must be tested for Morphine.

Dissolve the precipitate insoluble in excess of NaHO (or, if nothing has yet been discovered, dissolve the original substance) by dilute $H_2SO_4$ in slight excess, and add solution of $NaHCO_3$ until the acid reaction is neutralized, and allow to stand—

| | |
|---|---|
| The ppt. may contain<br>**Narcotine,**<br>**Quinine,**<br>**Cinchonine.**<br>A. | Evaporate the filtered solution to dryness, and dissolve in cold water; any residue insoluble in water may be **Codeine, Strychnine, Brucine, Veratrine,** and trace of **Quinine.**<br>B. |

## A. *Separation of Narcotine, Cinchonine, and Quinine.*

Dissolve the alkaloids in HCl, add Ammonia in excess, and shake up the ppt. with Ether; decant the etherial solution.

<table>
<tr><td rowspan="2">Test the residue for<br><b>Cinchonine.</b></td><td colspan="2">Evaporate the etherial solution; dissolve in HCl, dilute with 200 parts of water, neutralize the solution with $NaHCO_3$, and allow the liquid to stand for some time; a ppt. indicates <b>Narcotine</b>; filter.</td></tr>
<tr><td>To the ppt. apply special tests for <b>Narcotine.</b></td><td>Test the filtrate for<br><b>Quinine.</b></td></tr>
</table>

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* Sparteine is also a liquid base.

### B. *Separation of Strychnine, Brucine, Veratrine, (Codeine).*

Dry the precipitated alkaloids on the water bath; digest with absolute Alcohol, and filter.

The residue is **Strychnine.** Wash with absolute Alcohol, dissolve in Chloroform, divide the solution into several portions, evaporate these to dryness on porcelain dishes, and apply the colour tests for **Strychnine.**

Evaporate the Alcoholic solution to dryness on a water bath, and if Codeine has to be separated, digest in Ammonia; decant and evaporate the clear solution, and test it for **Codeine**; then test separate portions of the residue for **Brucine,** and for **Veratrine,** and, if necessary, for **Quinine,** of which a minute quantity may be present in this residue.

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## CHARACTERISTIC TESTS FOR THE PRINCIPAL ORGANIC BASES.

### I. VOLATILE BASES; OILY LIQUIDS.

**Aniline,** $C_6H_7N$ : slightly soluble in water; very soluble in Alcohol, Ether, and Chloroform.

1. Has a peculiar odour, is tinged brown by exposure, and stains deal yellow.
2. With Chloride of Lime produces a purple colour.
3. Heated with $HgCl_2$ crystals, produces a purple mass, soluble in Alcohol, giving a magenta solution.
4. A Sulphuric Acid solution, with Oxygen evolved at positive electrode of an electrolytic cell, is tinged blue, changing to violet and red.

**Conine,** $C_8H_{15}N$ : almost insoluble in water; soluble in Alcohol and Ether.

1. Has the odour of mice; intensely poisonous.
2. With $HNO_3$ gives a red colour.
3. With $H_2SO_4$ gives purple, then olive colour.
4. Is pptd. by $AuCl_3$, but not by $PtCl_4$, nor by Picric Acid if very dilute.
5. Coagulates a solution of Albumen.
6. With a solution of Iodine in KI gives a reddish-brown ppt.

**Nicotine,** $C_{10}H_{14}N_2$: soluble in water, Alcohol, Ether, and oils.

1. Has an odour of tobacco, and is tinged brown by exposure; pungent taste, very poisonous.
2. Is pptd. by $AuCl_3$, by $PtCl_4$, and by Picric Acid.
3. Does not coagulate solution of Albumen.
4. With solution of Iodine in KI gives a brownish-red ppt.

### II. NON-VOLATILE BASES—OF VEGETABLE ORIGIN.

**Morphine,** $C_{17}H_{19}NO_3$: Crystallizes in four-sided prisms; soluble in water and Alcohol, but not in Ether, nor in Chloroform; taste, bitter.

1. Is pptd. by NaHO, but is soluble in excess.
2. With $Fe_2Cl_6$ neutral, is tinged blue.
3. With $HNO_3$ conc., is tinged red; colour discharged by $SnCl_2$.

4. Heated with $H_2SO_4$, a colourless solution, changed when cold to violet by $H_2SO_4$ containing $HNO_3$; and further, to mahogany colour by $K_2Cr_2O_7$ crystals.
5. With $H_2SO_4$ and nascent Oxygen gives a series of colours.
6. Liberates Iodine from solution of Iodic Acid.

**Codeine,** $C_{18}H_{21}NO_3$: resembles Morphine in its physiological action, but does not answer to its characteristic tests. It is more soluble than Morphine in water, Ether, and Ammonia.

1. It is insoluble in excess of Soda.
2. With $HNO_3$ is tinged yellow.

**Narcotine,** $C_{22}H_{23}NO_7$: crystallises in rhombic prisms, insoluble in water; slightly soluble in Alcohol and in Ether.

1. With Chlorine water, then Ammonia, gives a yellowish-red liquid.
2. With pure $H_2SO_4$, and heated, gives a reddish colour; and with $H_2SO_4$, containing a trace of $HNO_3$, give a red colour.
3. With dilute $H_2SO_4$, then $MnO_2$, gives, when boiled and cooled, crystals of Opianic Acid.

**Quinine,** $C_{20}H_{24}N_2O_2$: crystallizes in tufts of silky needles; sparingly soluble in water (1 in 300), freely in Alcohol; soluble in Ether, &c.; taste, bitter.

1. Rotates a polarized ray to the left.
2. Solutions of its salts are fluorescent if no Hydracid is present.
3. Heated in a tube, gives a violet-red sublimate, and odour of Quinoline.
4. With Chlorine water, then Ammonia, is tinged bright green.
5. With Chlorine water, then $K_4Cfy$, then Ammonia, is tinged deep red.

**Quinidine** resembles Quinine, but is much less crystalline, and rotates a polarized ray to the right.

**Cinchonine,** $C_{20}H_{24}N_2O$: crystallizes in four-sided prismatic needles; insoluble in cold water; soluble in Alcohol; insoluble in Ether; taste, bitter.

1. Rotates a polarized ray to the right.
2. Heated in a tube, gives a violet-red sublimate, and odour of Quinoline.
3. With Chlorine water, then Ammonia, gives a yellowish-white ppt.

**Cinchonidine** rotates a polarized ray to the left.

**Strychnine,** $C_{21}H_{22}N_2O_2$: crystallizes in rhombic prisms; very slightly soluble in water and ordinary Alcohol, yet the solutions are intensely bitter; insoluble in absolute Alcohol and in Ether. The best solvents are Chloroform and Amylic Alcohol. Very poisonous.

1. With $H_2SO_4$, no change.*
2. The dry alkaloid, dissolved in a drop of pure strong $H_2SO_4$, gives a play of colours from purple-violet to red, with any of the following oxidizers,† if cold: $K_2Cr_2O_7$, $K_3Cfdy$, $MnO_2$, $PbO_2$, Oxygen at the positive electrode of an electrolytic cell. $MnO_2$ acts best.

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* *Papaverine gives a blue colour with $H_2SO_4$ alone.*

† *Curarine gives similar colour, but is insoluble in Chloroform.*

**Brucine,** $C_{23}H_{26}N_2O_4$: crystallizes in stars of prismatic needles; soluble in water and Alcohol, but not in Ether; taste, bitter.

1. With $HNO_3$ conc. is tinged bright red; when heated, yellow, which is further changed to violet by $SnCl_2$, or by $(NH_4)_2S$.
2. With $H_2SO_4$: rose colour, then yellow.
3. With Chlorine water, is tinged red, which Ammonia changes to yellow.

**Veratrine,** $C_{32}H_{52}N_2O_8$: crystallizes in small prisms; insoluble in water; soluble in Alcohol and Ether.

1. It has an acrid, burning taste, and causes violent sneezing when it reaches the membranes of the nose.
2. With heat, or with $HNO_3$, forms resinous masses.
3. With $H_2SO_4$, forms resinous masses, slowly becoming a red fluid.
4. By long boiling with HCl, a red colour.
5. With Chlorine water is tinged brown, changing to faint brown with Ammonia.

**Atropine, Daturine, or Hyoscyamine,** $C_{17}H_{23}NO_3$: crystallizes in silky needles; slightly soluble in Alcohol and in Ether; soluble in Chloroform; bitter; intensely poisonous; dilates the pupil.

1. With Baryta water, evaporated to dryness, and heated, odour of hawthorn blossom.
2. With HBr + Br, a yellow crystalline ppt.
3. Boiled with strong $HNO_3$, evaporated to dryness, and alcoholic solution of Caustic Potash added, violet colour, becoming red.

**Aconitine,** $C_{30}H_{47}NO_7$: does not crystallize well; slightly soluble in cold water; soluble in Alcohol, Chloroform, and Ether. One-tenth of a grain is poisonous: the minutest trace on the tongue produces tingling and numbness.

1. With $H_2SO_4$ becomes yellow, then a bad violet colour.
2. With sugar and $H_2SO_4$, red colour.
3. With Phosphoric Acid, violet.

**Caffeine, Theine,** $C_8H_{10}N_4O_2$: crystallizes in silky needles; soluble in water, Alcohol, and Ether; taste, bitter.

1. May be sublimed unchanged, but when boiled with NaHO solution is decomposed, evolving the fishy odour of Methylamine.
2. With $HNO_3$, evaporated to dryness, gives a red stain, changed to purple by cooling and adding Ammonia.

**Salicin.** $C_{13}H_{18}O_7$, is not a base, but resembles Quinine in appearance. Crystallizes in silky needles and scales, soluble in water and Alcohol, insoluble in Ether.

1. With $H_2SO_4$ conc., gives a red resinous mass.
2. Its solution, boiled with HCl, yields granular crystals, while sugar remains in the solution.

### III. BASE OF ANIMAL ORIGIN.

**Urea,** $CH_4N_2O$.: crystallises in prisms; very soluble in water and Alcohol; insoluble in Ether.

1. Heated, evolves Ammonia, &c., and yields a sublimate.
2. ,, with NaHO, or $Na_2CO_3$, evolves Ammonia.
3. A strong solution, with $HNO_3$, deposits crystalline plates.
4. ,, ,, Oxalic Acid, deposits tabular prisms.

## TABLE FOR ANALYSIS OF GASES.

*Note the colour and odour of the Gases.*
*Separate the Gases into two groups by a solution of Soda.*

I. Gases not absorbed by a solution of Soda. Test the gases by means of a lighted taper.

Not inflammable, but support combustion:

1. **Oxygen.**
2. **Nitrous Oxide.**

Not inflammable, but extinguish flame:

3. **Nitric Oxide.**
4. **Nitrogen.**

Apply a lighted taper to a small jar or tube of the gas.

Inflammable. Observe the colour of the flame, and test the products of combustion with lime water.

Products of combustion render lime water turbid:

5. **Carbonous Oxide**: flame blue.
6. **Acetylene**: flame yellow.
7. **Marsh Gas**: flame pale yellow.
8. **Olefiant Gas**: flame bright yellow.

Products of combustion do not render lime water turbid:

9. **Hydrogen**: flame colourless.
10. **Hydride of Phosphorus**: flame very bright, producing thick white fumes of $P_2O_5$.
11. **Hydride of Arsenic**: flame livid, odour of garlic; extremely poisonous.
12. **Hydride of Antimony**: flame bluish-white, producing white fumes.

*If the Gases explode on the application of a lighted taper, a mixture of Oxygen with combustible Gas is indicated.*

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1. **Oxygen** is absorbed by Pyrogallic Acid and solution of Soda, producing a black liquid; Oxygen is also absorbed by Ammoniacal solution of Cuprous Chloride, or by metallic Copper in the presence of solution of Ammonium Chloride and Ammonia.

2. **Nitrous Oxide** ($N_2O$) when exploded with Hydrogen, or heated with Potassium, leaves a residue of Nitrogen, whose volume is equal to that of the Nitrous Oxide employed.
3. **Nitric Oxide** ($N_2O_2$) is transformed into red fumes of Nitric Peroxide ($N_2O_4$) when mixed with air or Oxygen; it is absorbed by a solution of Ferrous Sulphate, forming a dark solution.
4. **Nitrogen** is characterized by its neutrality to all tests.
5. **Carbonous Oxide** (CO) is absorbed by an Ammoniacal solution of Cuprous Chloride. *As Oxygen is likewise absorbed by this solution, that gas must have been previously removed.* When CO is exploded in the Eudiometer, it requires half its own volume of Oxygen for complete combustion, and yields its own volume of $CO_2$ gas.
6. **Acetylene** ($C_2H_2$) gives a red ppt. with an Ammoniacal solution of Cuprous Chloride. When exploded, it requires two and a-half times its own volume of Oxygen for complete combustion, and yields twice its own volume of $CO_2$ gas.
7. **Marsh Gas** ($CH_4$) differs from Olefiant Gas in not being absorbed by Chlorine, Bromine, or fuming Sulphuric Acid. When exploded, it requires twice its own volume of Oxygen for complete combustion, and yields its own volume of $CO_2$ gas.
8. **Olefiant Gas** (Ethylene) ($C_2H_4$) forms liquid compounds with Chlorine and Bromine, and is absorbed by fuming Sulphuric Acid. When exploded, it requires three times its own volume of Oxygen for complete combustion, and yields twice its own volume of $CO_2$ gas.
9. **Hydrogen** is extremely light and diffusible, and when mixed with Chlorine explodes on the application of a lighted taper.
10. **Hydride of Phosphorus** ($PH_3$) is generally spontaneously inflammable in air.
11. **Hydride of Arsenic** ($AsH_3$), and 12. **Hydride of Antimony,** may be distinguished by introducing a cold white porcelain plate or dish into their flame, when a metallic deposit is obtained. The Arsenic deposit is dissolved both by Nitric Acid and by Sodium Hypochlorite. The Antimony stain is rendered white by Nitric Acid, and is unchanged by Sodium Hypochlorite.

II. Gases absorbed by a solution of Soda. These gases can generally be distinguished in the free state as well as after absorption by Soda.

Not inflammable:

13. **Ammonia** ($NH_3$) is liberated by boiling with NaHO, and is not absorbed by dry NaHO; but being very soluble in water it is absorbed by a cold solution of NaHO. It can be recognized by its odour, and by its alkaline reaction with reddened litmus paper. A trace of Ammonia dissolved in Nessler's solution (prepared by adding NaHO to a saturated solution of $HgI_2$ in KI solution) gives a reddish colour or precipitate.
14. **Sulphurous Oxide** ($SO_2$) has an odour of burning matches, and is soluble in water. It reduces an acid solution of Potassium Chromate to green; and forms a blue ppt. with a mixture of $Fe_2Cl_6$ and $K_3Cfdy$.